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A NEW GENUS AND SPECIES OF DIPLOGYNIID FROM NICARAGUA (ORDER ACARINA, FAMILY DIPLOGYNIIDAE)

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INTRODUCTION

In February, 1958, Mr. William O. Pfaeffle of the Servicio Tecnico Agricola de Nicaragua sent several hundred mites taken from a single specimen of the palm weevil, *Rhynchophorus palmarum* L., which was collected in El Recreo, Nicaragua, by Mr. William G. Bradley. The mites were attached to the legs and ventral surface of the elytra in large clusters. Examination of these specimens revealed an interesting complex of adult macrochelids, phytoseiids, and diplogyniids, in addition to a large number of nymphal uropodids which constituted the great majority of the mites.

DESCRIPTION

Crenamargo, new genus

Diagnosis. Margin of opisthosoma shallowly crenulate (Fig. 9, Plate II). Metasternal plates fused with sternal plate, resulting in the presence of four pairs of hairs. Anterior lobes of lateral plates prominent, similar to those of *Neolobogynium*. Two hairs on each lateral plate, the anterior pair close to the nonlobate part of the anterior margin, and the second pair close to the lateral margin. Vaginal sclerites curving medially and extending posteriorly into the posterior half of the lateral-plate area. Epigynial plate incompletely covered by lateral plates. Maxillary lobes of male hypostome short and rounded, each resembling somewhat an external ear.

Type species: *Crenamargo binuseta*, new species

FEMALE

Length. 1176 microns.
Width. 826 microns.
Shape. Ovate, broadly rounded anteriorly, slightly narrowed posteriorly. Very slight shoulders present.
Dorsum. (Fig. 1, Plate I). No exceptionally long hairs present. The longest hairs are located on the prosoma, there being three transverse rows of hairs. The most anterior row consists of only two longer hairs, the second and third rows possessing four hairs each. Remaining hairs are as shown in the figure.

Venter

Sternal plate. (Fig. 10, Plate III). Anterior margin shallowly concave. Posterior margin broadly and deeply concave, accommodating the well-developed anterior lobes of the lateral plates. Anterior angles rounded. Four pairs of hairs present. Hairs I longest and located submarginally in anterior angles. Hairs II smallest, widely separated from each other, and located directly posterior to hairs I in the posterior half of the median length of the plate. Hairs III slightly longer than hairs IV and separated from each other by a distance approximating 1/3 the width of the plate at that plane. They are located in the posterior 1/4 of the plate measured medially. Hairs IV, representing the metasternal hairs, are situated in the posterior flanges of the sternal plate, and are located most laterally of all sternal hairs. Three pairs of propeller-shaped or slit-like pores present. Pores I located in the anterior blade and immediately posterior (slightly median) to hairs I. Pores II posterio-median to hairs II and approximately equidistant between hairs II and III. Pores III posterio-lateral to hairs IV. There is no evidence of discrete metasternal plates. They are completely fused with the sternal plate.

Lateral plates. (Fig. 10, Plate III). Median 2/3 of the anterior margin occupied by well-defined lobes. Each plate roughly triangular and with rounded posterior margin. Median edges of the plates contiguous throughout most of their length. Two hairs on each plate. Hair I close to anterior margin of plate and to the lateral termination of median lobe. Hair I nearer lateral margin of plate than median margin. Hair II located in the posterior 1/2 of the plate and close to the lateral margin. Both hairs approximately equal in size and length. Vaginal sclerites clavate and with broadly arched arms terminating close together in the posterior half of the lateral-plate area. In some specimens the posterior part of an arm may be so displaced that the whole arm curves medially rather sharply, projects anteriorly, and may be located in the anterior 1/2 of the plate area.

Epigynial plate. (Fig. 10, Plate III). More than 2/3 of the surface covered by lateral plates. Exposed portion is chiefly in the posterio-median area.

Ventro-anal plate. Five transverse rows of hairs present. The first row has two hairs located medially to coxae IV. The second row has two hairs situated posterio-laterally to those of the first row. The third row has four hairs distributed in an anterio-lateral pair and a posterio-median pair. The fourth row consists of two hairs located lateral to the anterior portion of the anus. The fifth row has two hairs located posterio-medially to hairs of the fourth row. Two slit-shaped pores are located behind the anus and between the two hairs constituting the fifth row. The plate extends to the posterior margin of the body. Several slightly clavate hair-like processes are distributed over the plate, especially the median area. Each minute hair arises characteristically from either a hexagonal or heptagonal base.

Marginal plates. Well-developed with median areas underlapped by ventro-anal plate so that median margins are dorsal to ventro-anal plate. Anterior part of marginal plates projecting as far anteriorly as the area lateral to coxae III. Posterior 3/4 of lateral margin finely and shallowly crenulate. Marginal hairs smaller than those of ventro-anal plate.

Gnathosoma

Epistome. (Fig. 6, Plate II). Strongly and sharply mucronate at anterior apex with broad concavity on each side terminating in a sharp spur projecting anterio-laterally. Margin smooth.

Mandibles. (Fig. 8, Plate II). Lower jaw with nine teeth, exclusive of the large basal tooth, increasing in size from first to sixth, which is largest, then decreasing in size to the ninth. Projecting anteriorly from posterior, ventral surface of the lower jaw are two well-defined appendages: (1) a bushy, scopulate structure about half the length of the jaw; (2) a slender, elongate blade, pectinate on one margin, attenuated at the apex, and extending not quite to the tip of the jaw. Upper jaw with 12 teeth, excluding the basal tooth. The first four in a row separate from the remaining teeth, and increasing in size to the fourth which is largest. The second row of teeth, beginning with the fifth alongside the first row, increases in size to the tenth, eleventh and twelfth, of which the tenth and eleventh are largest.

Hypostome. (Fig. 4, Plate I). Four pairs of hairs present: I shortest, II longest, and IV stoutest and bipectinate. Maxillary lobes stoutly cornuate and longer than maxillary plates. The latter have two long, slender, attenuated appendages which extend much farther anteriorly than do the lobes. Styli close to lateral surface of plates, tapering gradually in the proximal 2/3, then more abruptly in the distal 1/3, each terminating in a fine filament which extends anterior to the body of the maxillary plates.

Holotype. Female taken by Mr. William G. Bradley, February 15, 1958, El Recreo, Nicaragua, on palm weevil, Rhynchophorus palmarum L. Retained in the writer's collection as number 58-5-7, Department of Zoology and Entomology, Iowa State College, Ames, Iowa.

Paratypes. Two females (numbers 58-5-8 and 58-5-9) and six males (numbers 58-5-1 to 58-5-6 inclusive) with same collection data as for holotype. One female paratype and three allotypes will be sent to the Ministerio de Agricultura y Ganaderia, Managua, Nicaragua. Remaining paratypes retained in writer's collection. Dimensions of paratypes are as follows with measurements in microns: 58-5-8--L. 1171, W. 803; 58-5-9--L. 1153, W. 803; 58-5-1--L. 1048, W. 733; 58-5-2--L. 1090, W. 742; 58-5-3--L. 1071, W. 741; 58-5-4--L. 1088, W. 752; 58-5-5--L. 1056, W. 724; 58-5-6--L. 1071, W. 761.

MALE. Description based mostly upon number 58-5-1.

Length. 1048 microns.

Width. 733 microns.

Shape. Similar to that of female.

Dorsum. Similar to that of female.

Venter. (Fig. 2, Plate I).

Sternal plate. Genital opening occupying approximately the median 1/3 of anterior margin. On the median, heavily-sclerotized, anterior part of the plate are two arcuate structures, each with spinous ridges radiating latero-posteriorly. Of the six pairs of intercoxal hairs, the sixth pair are located most medially. There are three pairs of slit-like pores. The first pair are between hairs I and II and may be on the heavily sclerotized, anterior part of the plate. The second pair of pores are

about equidistant between hairs II and III on each side, and are slightly medial to both pairs of hairs. Pores III are located lateral to hairs IV. A pair of minute hairs medial to hairs II. In the vicinity of and between hairs V and VI there are several pairs of minute hairs.

Ventro-anal plate. (Fig. 2, Plate I). Similar to that of female. The sixth pair of intercoxal hairs mentioned in the preceding paragraph correspond to the first pair of ventro-anal hairs of the female.

Marginal plates. (Fig. 2, Plate I). Similar to those of female.

Gnathosoma

Epistome. (Fig. 5, Plate II). Generally similar to that of female, excepting the slightly shorter and stouter median mucro of the male.

Mandibles. (Fig. 7, Plate II). Lower jaw with 18 teeth mostly uniform in size, the anterior 4-6 teeth being slightly subequal to the remainder. Projecting anteriorly from posterior, ventral surface of the jaw are two well-defined appendages: (1) a bushy structure comparable to that of the female; (2) a large, flattened, narrowed lamella slightly shorter than the jaw and with one margin noticeably sinuate. Upper jaw with two rows of teeth—a distal, short row of 5-6 teeth, of which the most proximal is conspicuously the largest; and a much longer row with from 10-14 teeth, exclusive of the basal tooth, and gradually increasing in size proximally.

Hypostome. (Fig. 3, Plate I). Four pairs of hairs present. I and III approximately the same length, II longest, and IV shortest. In comparison with corresponding hairs of the female, I of the male is longer, II shorter, III about the same length, and IV shorter. IV of both sexes conspicuously stout and bipectinate. Maxillary lobes short, rounded distally, and somewhat auriculate. Maxillary plates terminating in two long, narrow appendages which arise from the median area of the plates. Styli distinctly separate from lateral surfaces of plates, attenuated, but not as long as those of the female.

DISCUSSION

The shallowly crenulate, opisthosomal margin of Crenamargo is slightly similar to the body margin of Heterodiplogynium for which Trägårdh (1951) established the subfamily, Heterodiplogyniinae, characterized by the presence of a narrow band clothed with minute, perpendicular spinulae around the body margin of both sexes. In comparison with the remaining subfamilies of the family Diplogyniidae, Crenamargo is distinctly different from all except Diplogyniinae in which this new genus is placed.

Complete fusion of metasternal plates with the sternal plate characterizes Brachysternum as well as Crenamargo, and partial fusion is characteristic of Diplogyniella. Complete fusion results, typically, in the presence of four pairs of hairs on the "sternal" plate. Size and distribution of these hairs are distinctly different among Diplogyniella, Brachysternum, and Crenamargo. The size and shape of the anterior lobes of the lateral plates are grossly similar between Crenamargo and Diplogyniella, Lobogynium, Lobogynioides, and Neolobogynium.

The elongate, auriculate shape of the maxillary lobes of the male is distinctly different from the cornuate structures occurring on most

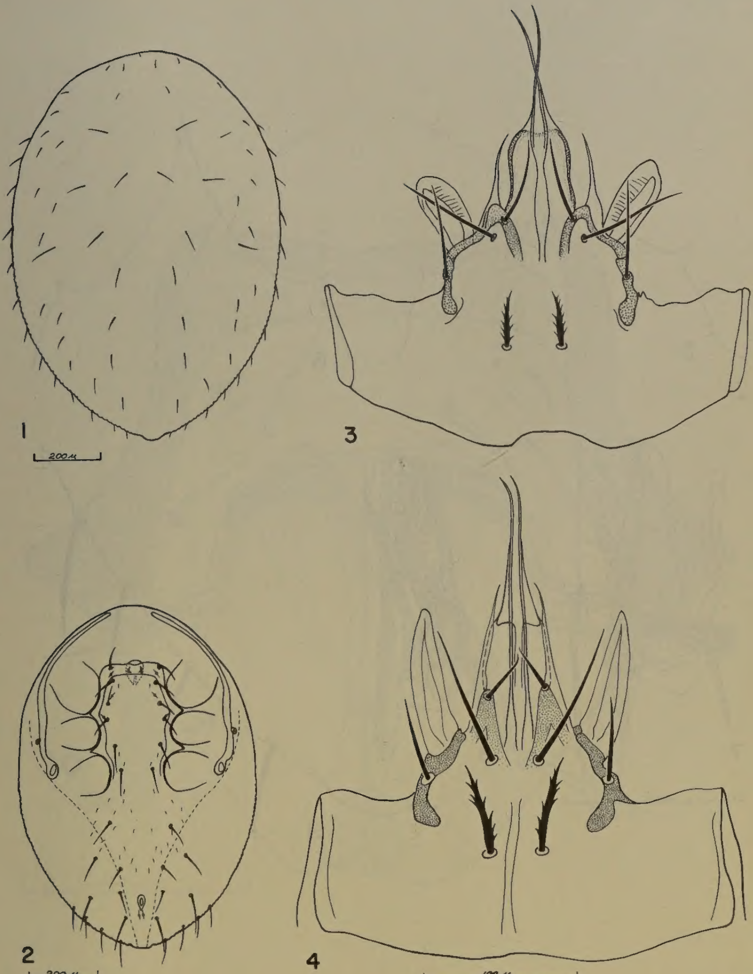

PLATE I

Crenamargo binuseta, new genus, new species

Fig. 1. Dorsum of female.
Fig. 2. Venter of male.
Fig. 3. Hypostome of male.
Fig. 4. Hypostome of female.

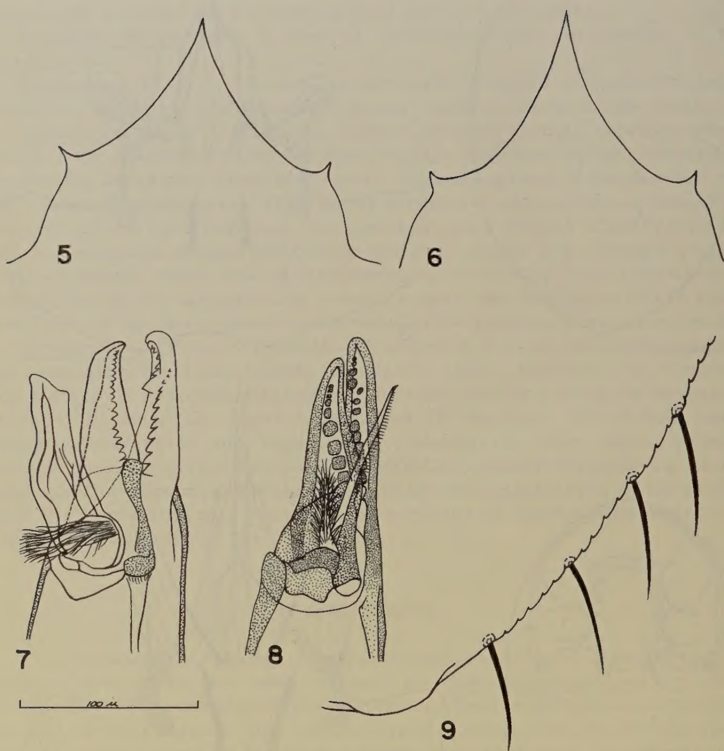

PLATE II

Crenamargo binuseta, new genus, new species

Fig. 5. Epistome of male.
Fig. 6. Epistome of female.
Fig. 7. Mandible of male.
Fig. 8. Mandible of female.
Fig. 9. Margin of opisthosoma of male and female.

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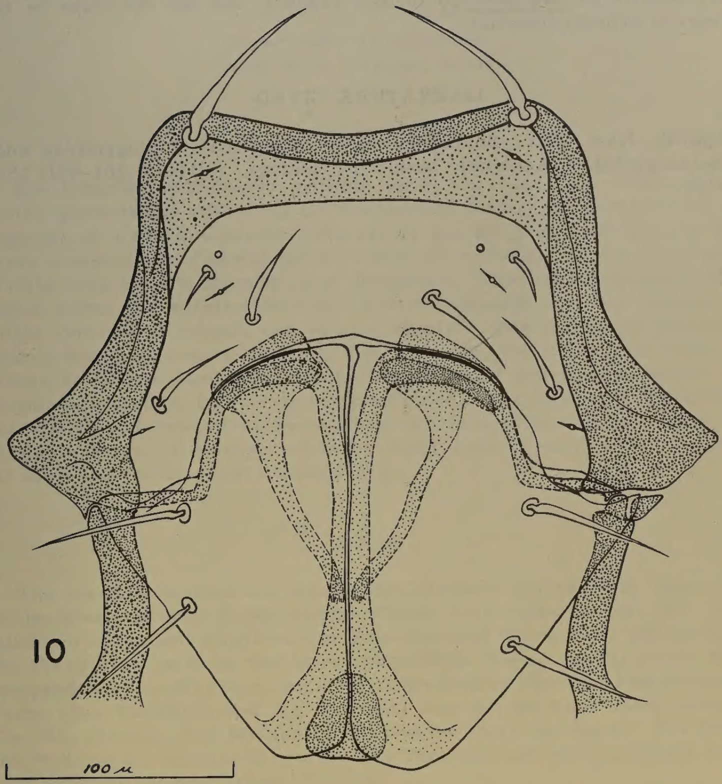

PLATE III

Crenamargo binuseta, new genus, new species

Fig. 10. Sternal, lateral, and epigynial plates of female.

females of the Diplogyniinae. Comparison of males shows a slight similarity between Crenamargo and Brachysternum and Diplogyniella. However, the lobes of Brachysternum are bluntly cornuate rather than auriculate; and those of Diplogyniella are thumb-shaped.

Another somewhat singular feature of the male is the lamellate mandibular appendage almost as wide as the lower jaw. Megachaetochela is most similar to Crenamargo in this respect, but the structure in the former is broadly flabellate.

LITERATURE CITED

Trägårdh, Ivar. 1951. Studies on the Celaenopsidae, Diplogyniidae and Schizogyniidae (Acarina). Arkiv för Zoologi, (2)1(4-5):361-451, 156 figs.

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SOLIDS-WATER-AIR SPACE RELATIONS OF SOME IOWA SOILS[1]

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INTRODUCTION

The distribution of solids, namely sand, silt, and clay, within a soil profile governs the water and air relations of a soil. If the water and air capacity of a soil are known, crop yields can be predicted (5). In this paper measurements of the solids-water-air relations of six Iowa soils at field capacity are reported and discussed. The measurements made which define the solids-water-air space relations are the volume of solids, volume of water, and volume of air. The volume of solids is broken down into volume of sand, silt, and clay; the volume of water is broken down into plant available water and plant unavailable water; the volume occupied by soil air is not subdivided. The terms plant available water and plant unavailable water are abbreviated to available and unavailable water. It is expected that further reports of this type of data for Iowa soils will appear subsequently.

SOILS

The six soils studied are the Ida silt loam and Monona silt loam both at the Western Iowa Experimental Farm near Castana; the Marshall silt loam at the Soil Conservation Experimental Farm near Shenandoah; the Floyd clay loam at the Carrington-Clyde Experimental Farm near Independence; the Webster clay loam at the Clarion-Webster Experimental Farm near Kanawha; and the Thurman loamy sand near Independence. The Ida, Monona, and Marshall soils are derived from loess. The Floyd and Webster are glacial till soils. The Thurman soil was developed from aeolian sands of local origin.

The soil profile studied was in each case the surface 5 feet. Under the Webster soil there was, when some of the data were obtained, a water table at 6 feet below the soil surface. Under the Floyd there was a water table 8 feet below the soil surface. Under the soils there was no water table within 20 feet of the surface.

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[1]Journal Paper No. J-3483 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 998.

[2]Research Associate of Soil Physics, Professor of Soils and Physics, and former graduate Assistant, presently Soil Scientist, Eastern Soil and Water Management Research Branch, SWCRD, ARS, USDA, respectively.

TERMINOLOGY

The spaces occupied by the solids, water, and air will be reported in percentages on a total bulk soil volume basis.

Solids having a diameter between 2 and 0.05 mm are defined as sand, between 0.05 and 0.002 mm as silt, and less than 0.002 mm as clay. Plant unavailable water is defined as the water in a soil when the soil cannot supply water at a sufficient rate to maintain turgor, with the consequence that the plant permanently wilts.

Most soils have an upper limit on the volume of water they are able to temporarily store. The moisture content at this upper limit is commonly called the field capacity. Field capacity may also be defined as that amount of water retained in a soil when, with time, the decrease in moisture content due to downward drainage is extremely small. The definition in this paper does not require the absence of a water table as does that of Veihmeyer and Hendrickson (8). In fact, two of the soils reported had the water tables noted. Plant available water is defined as the difference between the water at field capacity and the unavailable water. The water held in the soil at the field capacity will hereafter be referred to as FC water.

The volume not occupied by either soil solids or water at the field capacity is defined as the aeration porosity.

METHODOLOGY

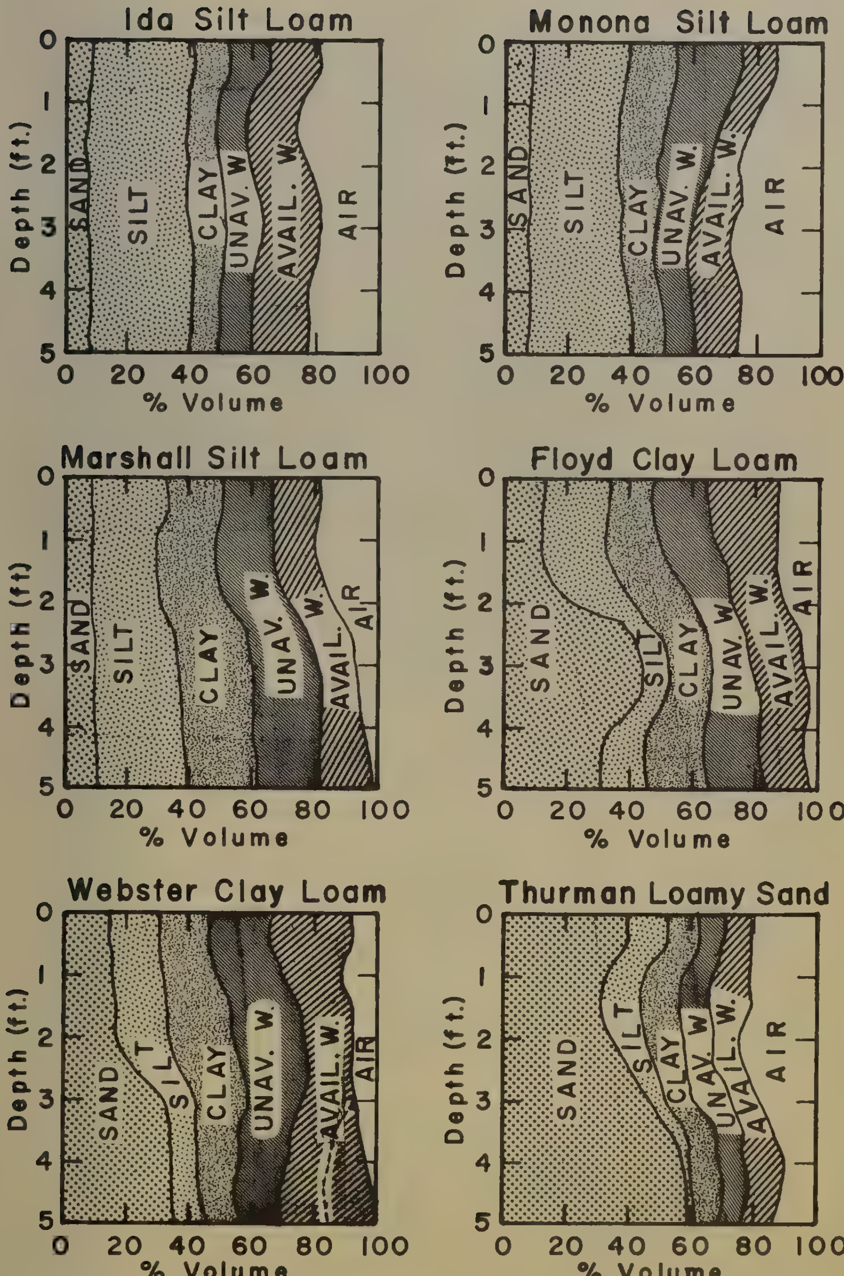
Four field plots were selected on each soil for determining the field capacity. Moisture content in the soil profile was determined to a depth of 5 feet at 6 inch depth intervals by a neutron scattering soil moisture meter. The neutron method is described by Stone et al. (7) and its application to field plot work is described by Burrows and Kirkham (2). Sufficient water was added to the soils to obtain the soil profiles at the field capacity at the time the moisture readings were made.

Unavailable water was measured using the 15-atmosphere percentage method (4). The 15-atmosphere percentage utilizes the fact that plants wilt if the soil water is held so tightly that 15 atmospheres or more of pressure are required to remove this tightly held water from the soil. Determinations of the 15-atmosphere percentages on a soil volume basis were made on soil samples from each depth at which field capacity was determined. (Recently 15 bars of pressure rather than 15 atmospheres has been used; for practical purposes 15 bars and 15 atmospheres are the same.)

Primary particle size analyses were made on each soil depth sample. The Bouyoucos hydrometer method was used (1). The aeration porosity was determined by subtracting from 100 the sum of the following percentages: field capacity, sand, silt, and clay.

RESULTS

Fig. 1 shows the results; the values are averages from the four plots of each soil. The amount of available water measured in the six Iowa


Ida Silt Loam
Monona Silt Loam
Marshall Silt Loam
Floyd Clay Loam
Webster Clay Loam
Thurman Loamy Sand
Depth (ft.)
0
1
2
3
4
5
% Volume
0
20
40
60
80
100
SAND
SILT
CLAY
UNAV. W.
AVAIL. W.
AIR

soils is represented in the figure by the area marked "avail.w.;" the unavailable water is designated as "unav.w.;" the amounts of solids are denoted by "sand," "silt," and "clay;" the aeration porosity is given by the area marked "air."

The amount of unavailable water stored in the loess-derived soils increases in the order Ida, Monona, and Marshall, but the Marshall does not contain as much available water as the Ida owing to the large volume of water space occupied by unavailable water. The FC water retained in the Monona soil is about the same as that of the Ida, but the amount of water available to plants is less in the Monona than in the Ida.

Ida contains the least clay and Marshall the most clay of the three loess-derived soils. Sand and silt contents within each of these soils are approximately constant throughout the 5-foot profile. There is, however, a slight decrease in silt content in the second foot of the Marshall soil. This decrease appears to have no effect on the amounts of either available or unavailable water in the soil. The percentages of soil air present in these loess soils at field capacity are all about 20 per cent, except that the Marshall soil has less air space below the 2-foot depth.

The Floyd and Webster clay loam soils differ from the loess-derived soils in that they contain about one-half as much air space (at the field capacity) as the loess soils. An approximately vertical broken line is shown in the available water space of the Webster soil. This line denotes the boundary between available water space and air space when the water table is at great depth; without the broken line, the figure represents conditions for the water table at the 6-foot depth, 1 foot below the bottom of the measured profile. With the water table at 6-foot depth, the Webster soil contains more total and available water than any other soil analyzed. Without the water table (or with a water table at great depth) the amount of available water retained in the lower 2 feet of the Webster soil is seen to be reduced to about one-half. For the Floyd soil, unlike the Webster, the water table was 3 feet below the bottom of the profile and because of this greater depth, the water table will have small effect on the water measured in the 5-foot profile. The plant available water stored in the Floyd clay loam exceeds 20 per cent at the soil surface and decreases with depth to 15 per cent at the 5-foot depth. The subsoils of the Webster and the Floyd contain more sand and less silt than their topsoils.

Less water is temporarily stored in the Thurman loamy sand than in any of the other soils studied. The total moisture content at field capacity is only about 20 per cent throughout the 5-foot profile. This soil contains more soil solids (about 60 per cent of the total soil volume) than any of the other soils. Its aeration porosity, as one would expect for a sand, is high compared to that of the Webster and Floyd soils.

DISCUSSION

Let us consider, in turn, the influence of clay, sand, and silt on the water relations in the soils.

Looking at the results (Fig. 1) for all six soils one may observe that the amount of unavailable water within a given soil is directly related to its clay content: where the clay content is higher, unavailable water is

higher and vice versa. This relation had previously been found for many Iowa soils by Nielsen and Shaw (3). Since the available water is the difference between the FC water and the unavailable water one should not conclude that when the FC water is high the amount of available water is high. Notice for example that the Ida soil is able to retain more available water than Monona soil; yet both retain about the same FC water. The Marshall soil retains more FC water than the Ida, but still has less available to plants than the Ida.

The increased sand content in the lower layers of the Webster and Floyd soils did not have a decreasing effect on the FC water. The presence of a normal water table in the Webster soil is responsible for high moisture content in its lower layers. Without the water table the broken line in Fig. 1 shows that the amount of available water in the Webster is about equal to that in the Ida. The Thurman soil, having no water table and a large fraction of its solids space occupied by sand, has the least available water of all the soils.

The data show that the silt content of all six soils has little influence on the amount of either unavailable or FC water retained in the soil; the unavailable water is a function of the clay content, not the silt content. The FC water is a function of the size, distribution, and continuity of the soil pores. It is known that the pore space of a soil is not determined by its silt content.

Fig. 1 shows that the proportions of sand, silt, and clay in a soil are not related in any definite way to the aeration porosity. The presence of the water table in the Webster soil decreased the volume of air in the lower soil layers. The distribution of air within the Marshall profile was similar to that in the Webster. The decreased air space in the lower layers of the Marshall must be attributed to the particular pore size distribution characteristic of the Marshall rather than the presence of a water table; there was no water table under the Marshall profile.

The relations in Fig. 1 bring out interesting differences between soil types in their ability to provide available water for plants. Nevertheless, owing to the variability of Iowa soils, the relations given in this paper should when applied be used with caution especially in application to experimental plots. In fact for accurate plot work on soil moisture the values represented in Fig. 1 should be determined for each plot. Shaw et al. (6) have discussed the sampling techniques associated with the variability problem.

SUMMARY

Measurements of the solids-water-air space relations of six Iowa soils at field capacity are reported and discussed. The relations for the soils are seen at a glance in Fig. 1. Solids relations were measured using a hydrometer technique. Field water relations were determined using neutron scattering.

LITERATURE CITED

1. Bouyoucos, G.J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. Agron. Jour. 43:434-438.
2. Burrows, W.C. and Don Kirkham. 1958. Measurement of field capacity with a neutron meter. Soil Sci. Soc. Amer. Proc. 22: 103-105.
3. Nielsen, D.R. and R.H. Shaw. 1958. Estimation of the 15-atmosphere percentage from hydrometer data. Soil Science 85: (in press).
4. Richards, L.A. and L.R. Weaver. 1943. The relation between 15-atmosphere percentage and the permanent wilting percentage. Soil Science 56:331-339.
5. Schwab, C.O., W.D. Shrader, P.R. Nixon, and R.H. Shaw. 1958. Research on irrigation of corn and soybeans at Conesville and Ankeny, Iowa 1951 to 1955. Iowa Agric. and Home Econ. Exp. Sta. Res. Bull. 458. Ames, Iowa.
6. Shaw, R.H., D.R. Nielsen, and J.R. Runkles. 1958. Evaluation of some soil moisture characteristics of Iowa soils. Iowa Agr. Exp. Sta. Bull. (in press)
7. Stone, J.F., Don Kirkham, and A.A. Reed. 1955. Soil moisture determination by a portable neutron scattering moisture meter. Soil Sci. Soc. Amer. Proc. 19:419-423.
8. Veihmeyer, F.J. and A.H. Hendrickson. 1931. The moisture equivalent as a measure of the field capacity. Soil Science 32: 181-193.

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EQUIVALENCE OF NORMS

Bernard Vinograde

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Let V be a vector space of finite dimension n over a field F which is complete with respect to a real-valued valuation φ. Let f be a real-valued norm function defined on V by

1) $f(u) > 0$ if $u \neq 0$, $f(0) = 0$, where $u \in V$,

2) $f(cu) = \varphi(c)\, f(u)$, $c \in F$,

3) $f(u + v) \leq f(u) + f(v)$.

The purpose of this note is to prove that all norm functions f are equivalent. That is, if (u^n) is a sequence in V, then $f(u^n) \to 0$ simultaneously for all norm functions f or for none.*

1. If we define $\|u\|$ by $\|u\| = \sqrt{\sum_i [\varphi(x_i)]^2}$, where $x_1, \ldots, x_n$ are the coordinates of u with respect to some fixed basis $\mu_1, \mu_2, \ldots, \mu_n$, then $\|\ \|$ is a norm function. For instance, since $\varphi(x_i) \geq 0$, we have

$$\sqrt{\sum_i [\varphi(x_i + y_i)]^2} \leq \sqrt{\sum_i [\varphi(x_i) + \varphi(y_i)]^2} \leq \sqrt{\sum_i [\varphi(x_i)]^2} + \sqrt{\sum_i [\varphi(y_i)]^2},$$

hence $\|u + v\| \leq \|u\| + \|v\|$, where $v = \sum_i y_i \mu_i$.

Now, $f(u) \leq [\max_i f(\mu_i)] \sum_i \varphi(x_i) \leq n\, [\max_i f(\mu_i)]\, \|u\|$.

Hence if $\|u^n\| \to 0$, then $f(u^n) \to 0$.

2. If $u \neq 0$ and $\varphi(x_M) = \max_i \varphi(x_i)$, then $[\varphi(x_M)]^2 \leq \|u\|^2 \leq n\, [\varphi(x_M)]^2$, hence $1 \leq \left\| \frac{u}{x_M} \right\| \leq \sqrt{n}$. Let $S = (v \mid v \in V,\ 1 \leq \|v\| \leq \sqrt{n})$.

Then S is a closed compact subspace of V in the metric $\|u - v\|$. To show that S is compact, consider any infinite subset (v^α) of S. Writing $v^\alpha = \sum_i x_i^\alpha \mu_i$ we have $1 \leq \sqrt{\sum_i [\varphi(x_i^\alpha)]^2} \leq \sqrt{n}$. Hence, for each i,

*This generalizes a well-known fact about complex finite-dimensional vector spaces. For the terminology used we refer the reader to B. L. van der Waerden, Moderne Algebra, Berlin, Julius Springer, 1937, Chapter X.

the set of real numbers $[\varphi(x_i^{\alpha})]$ is bounded, which implies the existence of a denumerable sequence in the set $[\varphi(x_i^{\alpha})]$ converging to a real number, say φ_i. Since the range of i is finite this process can be extended to all coordinates to obtain a sequence (v^{α^*}) in the set (v^{α}) whose coordinates $(x_i^{\alpha^*})$ are such that $\varphi(x_i^{\alpha^*}) \longrightarrow \varphi_i$, $i = 1, \ldots, n$. Furthermore, F being complete, we may deduce the existence of a number $x_i^* \varepsilon F$ such that $\varphi(x_i^*) = \varphi_i$, $i = 1, \ldots, n$. Thus $\| v^* - v^{\alpha^*} \| \longrightarrow 0$, where $v^* = \Sigma x_i^* \mu_i$, so S is compact. To show that S is closed we need merely show that $1 \leq \| v^* \| \leq \sqrt{n}$, which follows from $\left| \| v^* \| - \| v^{\alpha^*} \| \right| \leq \| v^* - v^{\alpha^*} \|$.

The norm function f is continuous in V, for if (w^n) is a sequence in V such that $\| w^n \| \longrightarrow 0$, then $f(w^n) \leq n \, [\max_i f(\mu_i)] \, \| w^n \| \longrightarrow 0$. Hence, f attains a positive minimum m in S.[1]

3. If $u \neq 0$, then $v = \dfrac{u}{x_M} \; \varepsilon \; S$, hence

$$\begin{cases} f(v) = \dfrac{f(u)}{\varphi(x_M)}, \\ \left\| \dfrac{u}{x_M} \right\| \leq \sqrt{n} . \end{cases}$$

Therefore $\| u \| \leq \sqrt{n} \;\; \varphi(x_M) = \sqrt{\dfrac{n}{f(v)}} \; f(u) \leq \sqrt{\dfrac{n}{m}} \;\; f(u)$.

Hence if $f(u^n) \longrightarrow 0$, then $\| u^n \| \longrightarrow 0$. But f is arbitrary, so all norm functions are equivalent.

4. It is now readily seen that a sequence (w^n) in V is a Cauchy sequence for every norm function if it is for one norm function. Furthermore, if $\| w^p - w^q \| \longrightarrow 0$, then $\varphi(z_i^p - z_i^q) \longrightarrow 0$, where $w^p = \sum_i z_i^p \mu_i$. Hence, as in proving the compactness of S, we may show that there exists a coordinatewise limit $w = \sum_i z_i \mu_i$ for this norm function. But $f(w^n - w) \leq \sum_i \varphi_i(z_i^n - z_i) \; f(\mu_i)$ implies that w is the limit of this sequence (w^n) for every norm function. This limit is easily shown to be unique.

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TROLENE AND DOWCO 109 AS FEED ADDITIVE FOR GRUB CONTROL[1]

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In the past several years many papers have been published on the success or failure of certain systemic insecticides for cattle grub control (Hypoderma sp.). Several methods have been employed in administering the insecticides. These methods include boluses, sprays, drenches, injections, and feed additives. At the present time two systemic insecticides have been approved by the Pure Food and Drug Administration for commercial use in cattle grub control. These two are Trolene[2] (Dow ET-57) as a bolus and Co-Ral[3] (Bayer 21/199) as a spray.

Knapp et al. (1958) reported results of cattle grub control by placing a Trolene formulation in a pelleted feed. The feed was rationed to each test animal so that each received approximately 110 mg of Trolene per kg of body weight. Sturdy (1958) fed Trolene (Dow ET-57) continuously, incorporated in the protein supplement, at different levels for 8 months. All treated animals were grub-free, while the untreated animals had an average of 30.8 grubs per steer. No gross pathology was observed in the slaughtered steers. Histological microscopic sections indicated that there were no abnormalities due to Trolene.

Experimental Procedure

A wettable powder formulation containing 25 per cent Trolene and 10 per cent Dowco 109[4] impregnated on a 15 per cent protein wheat germ powder were used as feed additives. Dowco 109 is the experimental name for O-(4-*tert*, butyl-2-chlorophenyl) O-methyl methyl phosphoramidothioate. Trolene is O,O-diethyl O(2, 4, 5-trichlorophenyl) phosphorothiote.

On October 22, 1957, at Waterloo, Iowa, tests were begun to compare the efficacy of Trolene and Dowco 109 as low level feed additives for control of the cattle grubs. In addition, this test was designed to obtain data on the weight gain and feeding efficiency of cattle treated with these two materials, compared with a pen of animals in which grubs were left

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[2]Trade mark of the Dow Chemical Company.

[3]Trade mark of the Chemagro Corporation.

[4]Experimental material of the Dow Chemical Company.

uncontrolled. This study was made in cooperation with the Rath Packing Company at their Hill Top feed lot.

The 84 steers used in this study were from near Livingston, Montana, where they had spent the heel fly season. The test animals were composed of 36 crossbred Hereford-Angus and 48 Hereford steers all from the same ranch. All steers were ear-tagged and individually weighed. The group of steers was randomly split into three lots. Each lot contained 12 crossbreds and 16 Herefords. The lots were designated at random to receive either Dowco 109 or Trolene in their daily feed ration, or no insecticide.

Dowco 109 was administered to Lot B by mixing 3 pounds of the 10 per cent formulation with 137 pounds of soybean meal. The soybean-Dowco 109 supplement was added to a 6 day feed supply. All mixing was done by the Rath Packing Company, using equipment designed to mix trace elements. The day's feed was placed in a feed bunk long enough to accommodate all animals at once. The steers cleaned up their daily ration in all cases. In this manner a 744 pound steer eating 1/28 of the daily ration would receive 2.4 mg of Dowco 109 per kg body weight each day for 6 days.

The cattle in Lot C received a total of 13.75 pounds of 25 per cent Trolene wettable powder in 6 days in the same manner as Lot B. Each steer received approximately 35 mg of Trolene per kg of live weight for each of 6 consecutive days.

No signs of sickness or lack of appetite attributable to the insecticides were observed throughout the feeding period. Two steers were slaughtered before the end of the feeding period due to causes unrelated to the insecticides used earlier.

Feed consumption records were kept for each lot, and from these the cost per 100 pounds of gain was computed.

On April 2, 1958, each steer was individually weighed and assigned a "kill" number to be used in the packing plant. In this way each animal's identity was preserved so that it could be observed after slaughter. The next day all steers were slaughtered. Grub counts were made by examining the underside of each hide immediately after the steers had been skinned and by counting the grubs present in the subdermal fat of the loin region. The trimming necessary because of the presence of grubs was kept separate for each treatment.

Results

All the untreated steers in Lot A were infested with grubs. The average was 12.3 grubs per steer. The range of grub numbers was from 2 to 25.

Of the steers that received Dowco 109 (Lot B), only 29.6 per cent were infested with grubs. The average was 0.4 grub per steer. The range of grubs was 0 to 4.

Only 10.7 per cent of the steers receiving Trolene (Lot C) were infested with grubs. The average was 0.25 grub per steer. The range was from 0 to 5.

When compared with the untreated steers, 96.7 per cent control of the cattle grubs was obtained with Dowco 109 and 97.8 per cent control with Trolene (Table 1).

Table 1. Dowco 109 and Trolene used as low-level feed additives for grub control. Waterloo, Iowa. 1957-1958.

	Lot A Untreated	Lot B Dowco 109	Lot C Trolene
Total no. grubs per lot	332	11	7
Avg. no. grubs per steer	12.3	0.4	0.25
Range of grub numbers per lot	2-25	0-4	0-5
Per cent steers infested	100.0	29.6	10.7
Per cent grub control	--	96.7	97.8

The control steers (Lot A) gained an average of 393 pounds per steer. Those that received Dowco 109 gained an average of 397 pounds per steer. The steers that received Trolene gained an average of 417 pounds. These weight gains were made during a 162-day period. (Table 2).

An analysis of covariance showed no significant difference between the weight gains of lots A, B, and C. There were no significant differences between the treated and untreated steers in respect to (1) number of condemned livers, (2) dressing percentages, (3) carcass grades, and (4) actual selling prices (Table 2).

Table 2. Effects of grub control by systemic insecticides as feed additives at Waterloo, Iowa. 1957-1958.

	Lot A Untreated	Lot B Dowco 109	Lot C Trolene
No. of steers per lot	27	27	28
Avg. starting weight	722	744	755
Avg. gain per steer	393	397	417
Feed required for 100 lbs. gain	932.0	970.5	907.5
Cost of gain per 100 lbs.	$ 18.34	$ 19.51	$ 18.19
Margin per steer over feed cost	82.90	80.65	88.30
Dressing percentage	61.47	62.13	61.77
Carcass grades	Prime 2 Choice 18 Good 7	Prime 2 Choice 14 Good 11	Prime 1 Choice 21 Good 2

The cost of gain per 100 pounds for the untreated steers was $18.34. The Dowco 109 and Trolene treated steers cost $19.51 and $18.19 per 100 pounds of gain respectively.

The untreated steers showed a profit of $82.90 per steer over total costs. The margin for the Dowco 109 treated steers was $80.65, and for the Trolene treated steers $88.30.

Approximately 30 pounds were trimmed from the carcasses of the untreated steers due to the presence of grubs while only 5 pounds and 1/4 pound were trimmed from the Dowco 109 and Trolene treated steers respectively.

ABSTRACT

Trolene and Dowco 109 were administered as feed additives at the rate of 35 mg and 2.4 mg respectively per kg of body weight on each of 6 consecutive days to 28 steers each. A lot of 28 untreated steers served as controls. The Trolene treatment gave 97.8 per cent control of the grubs. Dowco 109 controlled 96.7 per cent of the grubs. Differences in weight gain, condemned livers, dressing percentage, carcass grade, and selling price of the 2 treated lots and the control lot of steers were not statistically significant. Profits over total costs were $82.90 per steer in the untreated lot, $80.65 per steer in the Dowco 109 treated lot, and $88.30 per steer in the Trolene treated lot.

REFERENCES

Knapp, F.W., C.J. Terhaar, and C.C. Roan. 1958. Field studies with feed and bolus formulations of Dow ET-57 for control of cattle grubs. Jour. Econ. Entomol. 51:119-122.

Sturdy, R.A. 1958. Successful tests indicate cattle grubs controlled by including toxicant in feed. Croplife 5(32):6.

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FIELD TESTS WITH THE FUNGUS BEAUVERIA SP. FOR CONTROL OF THE EUROPEAN CORN BORER[1]

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The fungus Beauveria is known to infect and kill a number of insects. Charles (1941) listed 29 species or families as hosts of B. bassiana (Bals.) Vuill. and 88 for B. globulifera (Speg.) Pic. According to Faucett (1944), B. globulifera had been reported on at least 60 species in North America. Steinhaus (1949) reported 30 species as hosts of B. bassiana in North America and additional hosts in other parts of the world.

Probably the first work with Beauveria on the European corn borer (Pyrausta nubilalis (Hbn.)) was that reported by Metalnikov and Toumanoff (1928) in Europe. In the United States Lefebvre (1931) carried on laboratory experiments with B. bassiana and B. globulifera. He noted a fairly persistent difference in growth habit between the two species, and also a difference in mortality of the European corn borer, which he was using as a host insect.

In field experiments Bartlett and Lefebvre (1934) used cornstarch and wheat flour as carriers for spores of B. bassiana to control the European corn borer. They applied from 3 to 300 grams of spores per acre, in one to five applications. Mortality due to the disease ranged from 1 to 79 per cent. They concluded that, although the amount of spores per acre was important, a number of other factors should be considered, and also that mortality based on number of live and dead larvae found was probably low, as small dead larvae might not be recovered.

Stirrett, Beall, and Timonin (1937) obtained a maximum of 63 per cent reduction of European corn borer larvae by the application in flour of 40 grams of spores per acre. Time of application was considered of greater importance than rate. In later work (Beall, Stirrett, and Conners 1939) two rates of spores were applied on three dates 5 days apart, and the mortality increased on the later dates of application. A 10-gram dosage gave 54, 60, and 67 per cent reduction, and a 40-gram dosage gave 62, 66, and 71 per cent.

Several factors have prompted a revival of work with Beauveria for control of the European corn borer. First, and probably the most important, has been the problem of insecticide residues. Although generally satisfactory control can be obtained with DDT, an appreciable

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[2]Cooperating with the Department of Zoology and Entomology, Iowa Agricultural Experiment Station.

residue persists on the plants (Fahey, Brindley, and Rusk 1953). Furthermore, this residual DDT accumulates in the fatty tissue of beef animals fed on treated plants (Fahey, Brindley, and Spear 1955). Control with Beauveria would eliminate the residue hazard.

Other factors included the borers' possible development of resistance to insecticides as well as the possibility of an accumulation of insecticides in the soil to a deleterious level. In addition, the development of granulated insecticides and their use in European corn borer control (Cox, Brindley, Lovely, and Fahey 1956) opened a new possibility for the application of disease organisms in a similar manner.

PROCEDURES

Methods of producing spores in large quantities had been developed (Bartlett and Lefebvre 1934, McCoy and Carver 1941, and Dresner 1949). The method used for this work was a slight modification of that of McCoy and Carver except that equal parts of bran and water were used. The inoculum was obtained from diseased borers that were found during parasite studies. Spores were transferred to corn meal–agar slants in order to obtain pure cultures. After the spores had matured they were transferred to the sterilized bran-water mixture. Transfers were usually made by rubbing a sterile needle over the agar culture and then flipping the spores into flasks containing sterile bran. The spores were distributed through the media by shaking.

After 5 to 6 days at 80°F, or 6 to 8 days at room temperature, the Beauveria-bran mixture was removed from the flasks and placed on clean papers to dry. Drying was done in an unheated building and usually required about 1 week. When dry the material was placed in paper sacks and returned to the heated building. There was no apparent reduction of viability or virulence after several months' storage. Spores for field application were obtained by working the dry bran-Beauveria misture over a 30-mesh screen. This procedure gave a mixture of Beauveria spores and mycelia and small bran particles.

Beauveria spores were applied to the corn plants in sprays, dusts, and granulated carriers. Although all methods gave an appreciable mortality, the first season's work indicated a slight advantage with the granulated carriers. The second season's work was therefore confined to the granulated carriers.

Sprays were either in water or water with a wetting agent or detergent. Laboratory tests with the wetting agent Triton X-155 or the detergent Trend at 1 part to 100 parts water had no detectable adverse influence on the spores. This was far in excess of the amount that would normally be used in field work. Also a pressure of 40 pounds per square inch and subsequent release through a spray nozzle had no detectable influence. Sprays were applied with a knapsack sprayer.

The only dust used contained flour as the diluent. This was applied with a hand duster.

Granulated carriers were of two types, attapulgite 30-60 AA granules and corn meal. The corn meal was placed in an oven at 250°F for 2 hours to destroy molds and other organisms. Different amounts of spores

were used per unit of carrier. The granules were applied by dropping small amounts over the plants by hand. The funneling action of the leaves concentrated this material in the whorls and leaf axils.

The method of determining the reduction in the larval population was to compare the number of living larvae in the treated plots to those of the check plots. Although a number of dead larvae were observed, obviously killed by Beauveria, no attempt was made to utilize these data for determining mortality. The examination for larvae consisted of checking the leaves, including the whorl, and the leaf sheaths, then slicing the plant into sufficiently small sections to locate those larvae that had tunneled into the stalk. The leaf midribs were also carefully checked as this was a favorite place for tunneling of the young larvae.

Usually 20 plants per plot were examined, although sometimes this was reduced to 10. In 1955 the selection of these plants followed a set pattern, but in 1956 they were picked at random from the two center rows of four-row plots. On wider plots they were taken from any of the rows except the border rows.

RESULTS AND DISCUSSION

The results of preliminary experiments on the first brood in 1955 are shown in Table 1. It may be noted that in four tests where corn meal was compared with one or more carriers the corn meal gave the best results in all cases. These results were considered quite encouraging since only 0.02 inch of precipitation was recorded during a 14-day period from the time of application until the first dissections were made. Generally entomogenous fungi, to be effective, are considered to be quite dependent on high humidity or moisture of some type and proper temperature. In the case of corn plants this moisture was present in the whorls and leaf axils even under very dry conditions. Corn plants are rather unusual in this respect and one should not expect similar results with other types of plants.

Table 1. Per cent mortality of first-brood European corn borer larvae from Beauveria spores applied in various carriers, 1955.

Date of application	Corn meal	Attapulgite granules	Water	Water plus detergent	Flour
June 11	69	--	--	--	--
14	80	74	--	--	--
14	--	--	0	0	--
17	89	64	--	--	--
22	93	90	--	68	--
24	91	82	67	82	74

Only one test was conducted on the second brood in 1955. Five methods of applying spores were used. Results in all cases were poor, ranging from 42 to 25 per cent mortality.

In 1956 the method of application of spores was confined to sterilized corn meal and attapulgite granules. Experiments were designed primarily to give information on time of application and amount of spores per unit of carrier for control of first-brood larvae. In this work the materials were applied by hand. In addition, four experiments were carried out using the mechanical applicator. Two of these experiments were against the first brood and two against the second brood.

Results of the work on time of application, using 1 gram of Beauveria spores to 500 grams of carrier, are given in Table 2. The increase in rate of application was not intended, but resulted from an attempt to get a good coverage of the larger, rapidly growing plants. As a result the increased kill as the season progressed could have been due to the increase in material applied rather than the time of application.

The effect of spore concentration in the carriers on the corn borer control is given in Table 3. In three of the four tests the control increased with the amount of spores.

Table 2. Effect of time of application on control of first-brood European corn borer larvae with 1 part of Beauveria spores in 500 parts of carrier.

Date of application	Corn meal: Pounds per acre	Corn meal: Per cent control	Attapulgite granules: Pounds per acre	Attapulgite granules: Per cent control
June 15	9.7	64	8.0	34
20	8.2	49	7.7	59
25	12.1	86	11.1	59
29	12.8	90	11.2	76

While the experiments were in progress, casual observations indicated that mortality of borers was not as high as in 1955. Since the procedure followed in 1955 was to mash the bran-Beauveria mixture by hand, then mix the entire lot with the carrier, this was tried again as the last experiment for the first brood. Fifty and 100 gram lots of the bran-Beauveria mixture were incorporated with 500 grams of carrier. This was applied at 25 pounds per acre, rather late in the season when some of the borers had reached the fifth instar and were tunneling in the stalk. In spite of the lateness of the application, the mortalities from four treatments were 78, 88, 93, and 98 per cent.

Treatments for the first brood with the mechanical applicator were made in two fields using one part Beauveria spores to 500 parts granulated attapulgite applied at the rate of 20 pounds per acre. Plant height varied considerably between the two fields, one being 5 to 6 feet tall and the other 2 to 3 feet. Control was very poor, being only 31 and 33 per cent.

Table 3. Effect of different concentrations of Beauveria in two carriers on the control of first-brood European corn borer larvae, 1956.

	1 part Beauveria		2 parts Beauveria		3 parts Beauveria		No Beauveria	
Date	Pounds per acre	Per cent control	Pounds per acre	Per cent control	Pounds per acre	Per cent control	Pounds per acre	Per cent control
				In 500 parts corn meal				
June 18	8.9	69	8.9	55	--	--	10.6	+45
22	9.8	69	--	--	10.0	87	--	--
				In 500 parts attapulgite granules				
19	10.4	33	11.6	41	--	--	8.8	+21
22	9.9	44	--	--	10.8	80	--	--

Control of the second brood, as in 1955, was also very low. A reduction of 34 and 38 per cent resulted from 1 and 2 parts of Beauveria spores per 500 parts of attapulgite granules applied at 20 pounds per acre in the first test. In the second test applied one week later the reduction was only 11 and 15 per cent for the 1 and 2 grams.

Health hazard in handling Beauveria

The literature on Beauveria gave no indication of any injurious reaction of the organism to human beings. Since it is a facultative parasite of insects growing readily on grain and a number of artificial media, it was assumed there would be no influence other than that from rust or mold spores. However, in working with Beauveria where there was considerable spore dust the writer suffered a marked reaction. This was not definitely attributed to Beauveria on the first two occasions, although there was some suspicion of it.

Within about 2 hours after exposure to spores in the air, a general aching and weakness was noted, followed by a slight chill which lasted for about an hour. During most of the night there was a fever, considerable perspiration, and increased aching. By morning these symptoms had passed, leaving only a somewhat weakened condition. Symptoms were so typical of flu that it was believed to be this, since no reaction to Beauveria had been reported previously.

Several days later another batch of Beauveria was sacked. This time, to be on the safe side in case Beauveria had caused the trouble, a respirator was worn. In spite of this protection a reaction similar to the first followed except that there was no chill at the start. Several weeks later, while Beauveria was being screened onto an inert granulated carrier, a third reaction was experienced in spite of the respirator. In all three instances it was moderately warm and a short-sleeved shirt was worn. In subsequent work a long-sleeved shirt and rubber gloves were worn, and on completion of the work a thorough shower was taken. With these precautions no further reactions resulted. It was presumed that the reaction was due chiefly to exposure of the skin to heavy concentrations of the spores rather than to inhalation. Considerable work has been done with Beauveria mixed with carriers and no ill effects have been noted.

Although there may be considerable differences between individuals, there seems to be a definite health hazard in exposure to heavy concentrations of the dry Beauveria spores. After these reactions were reported to the Washington, D.C. office, S.R. Dutky mentioned a previous but comparable reaction in the careless handling of Beauveria at the Beltsville laboratory.

SUMMARY

The fungus Beauveria sp. was grown on sterile bran in the laboratory. Spores from these cultures were applied to corn plants by different methods for control of European corn borer larvae.

In 1955 sterilized dry corn meal as a carrier of the spores gave an average larval reduction of 91 per cent while granulated attapulgite gave 79 per cent. Sprays and a dust produced appreciable mortalities but were not as effective as the corn meal.

In the 1956 experiments corn meal as a carrier continued to produce somewhat higher mortalities than attapulgite granules. Increases in the amount of spores gave increases in control.

Experiments for control of second-brood larvae were relatively ineffective both years.

The writer experienced marked debilitation from exposure to heavy concentration of the spores; therefore, anyone working with the organism should use proper precautions when working with large quantities.

REFERENCES

Bartlett, K.A. and C.L. Lefebvre. 1934. Field experiments with Beauveria bassiana (Bals.) Vuill., a fungus attacking the European corn borer. Jour. Econ. Ent. 27(6):1147-57.

Beall, Geoffrey, George M. Stirrett, and I.L. Conners. 1939. A field experiment on the control of the European corn borer Pyrausta nubilalis Hubn., by Beauveria bassiana Vuill. II. Sci. Agric. 19(8):531-4.

Charles, Vera K. 1941. A preliminary check list of the entomogenous fungi of North America. U.S. Bur. Ent. and Plant Quar., Insect Pest Survey Bull. 21, suppl. 2, No. 9, pp. 707-85.

Cox, H.C., T.A. Brindley, W.G. Lovely, and J.E. Fahey. 1956. Granulated insecticides for European corn borer control. Jour. Econ. Ent. 49(1):113-19.

Dresner, E. 1949. Culture and use of entomogenous fungi for the control of insect pests. Boyce Thompson Inst. Contrib. 15(6):319-35.

Fahey, Jack E., T.A. Brindley, and H.W. Rusk. 1953. Three years' study of DDT residues on corn plants treated for European corn borer control. Iowa State College Jour. Sci. 28(2):209-60.

_____, _____, and M.L. Spear. 1955. DDT residues in fat from steers pastured on corn stover in DDT-treated fields. Jour. Econ. Ent. 48(5):606-7.

Faucett, H.S. 1944. Fungus and bacterial diseases of insects as factors in biological control. Botan. Rev. 10:327-48.

Lefebvre, C. L. 1931. Preliminary observations on two species of Beauveria attacking the corn borer, Pyrausta nubilalis Hubner. Phytopathology 21(12):1115-28.

McCoy, E.E. and C.W. Carver. 1941. A method of obtaining spores of the fungus Beauveria bassiana (Bals.) Vuill. in quantity. Jour. N. Y. Ent. Soc. 49:205-10.

Metalnikov, S., and C. Toumanoff. 1928. Experimental researches on the infection of Pyrausta nubilalis by entomophytic fungi. Intern. Corn Borer Invest. Sci. Repts. 1:72-73.

Steinhaus, E. A. 1949. Principles of insect pathology. McGraw-Hill Book Co., New York, pp. 1-757.

Stirrett, George M., Geoffrey Beall, and M. Timonin. 1937. A field experiment on the control of the European corn borer, Pyrausta nubilalis Hubn., by Beauveria bassiana Vuill. Sci. Agric. 17(9):587-591.

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PARTICLE NUMBERS OF GRANULATED CARRIERS IN RELATION TO EUROPEAN CORN BORER CONTROL[1]

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SUMMARY

Granulated insecticides for European corn borer control have been studied at the European Corn Borer Research Laboratory, Ankeny, Iowa, since 1953. The effects of the particle number of granular carriers and application rates of granular carrier and toxicant were studied in 1956 and 1957. There was evidence that the number of particles of a granular carrier distributing the toxicant does not affect the efficiency of the toxicant. Of the three carriers tested, vermiculite was a slightly poorer carrier.

In the rate of application study, the rate of toxicant seemed to be the controlling factor in determining the borer control. If a constant amount of toxicant is applied per acre, equal control can be obtained with 10 or 20 pounds of granular carrier per acre.

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Studies on granulated formulations of insecticides for control of the European corn borer (Pyrausta nubilalis (Hbn.)) have been conducted at the European Corn Borer Research Laboratory, Ankeny, Iowa, since 1953. Cox et al. (1956a and 1956b) reported on the progress of investigations carried on in 1953, 1954, and 1955 emphasizing comparisons of insecticides, formulations, rates and time of application. Lovely et al. (1956) studied various types of granular applicators while Fahey et al. (1956) reported on residues remaining after treatment with granular insecticides. The investigations reported herein were conducted in 1956 and 1957 to study the effect of the number of particles of granular carriers and rates of application on European corn borer control.

The term "particle number," as used here, denotes the number of particles per unit of weight. If 10 pounds of each carrier were applied to a given area at one rate of toxicant, attapulgite would have more than twice as many particles as bentonite distributing the toxicant over that area which could affect the efficiency of the toxicant. Therefore, these experiments were designed to test the hypothesis that the number of particles of a granular carrier per unit area, if having the same amount

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of toxicant applied to that area, will influence the toxicants efficiency in control.

MATERIALS

The granular carriers used were 30/60 mesh RVM-AA attapulgite, 20/60 mesh sodium bentonite, and No. 4 expanded vermiculite which have bulk densities of 27 to 31 pounds, 67 pounds, and 12 to 13.5 pounds per cubic foot, respectively. In the order given they contain approximately 12,300,000, 5,900,000, and 27,500,000 particles per pound. Since the number of particles applied per acre is so large, for practical purposes in these investigations attapulgite is considered to have twice as many particles as bentonite, and vermiculite twice as many as attapulgite. The toxicants used to examine the effects of particle numbers may be noted from the tables.

GENERAL PROCEDURE

The design of each experiment was a randomized, complete block with the exception of four experiments in 1957. Experiments comparing the three carriers impregnated with endrin or toxaphene were split plot designs with the carrier on the whole plot and toxicant on the subplot. The experiments comparing three rates of DDT, with each rate on three levels of carrier per acre, were also on split plot designs.

All treatments were replicated four times on experimental plots that were four rows wide. In 1956 the plots were 130 feet long for first brood experiments and 140 feet long for second brood. In 1957 the plot lengths were reduced to 100 feet in an attempt to decrease the variation between replicates.

The first generation experiments in 1956 were treated on June 21 when 35 per cent of the plants showed evidence of leaf feeding. Due to the low borer population, 10 plants which showed evidence of leaf damage were tagged before the treatments were applied and dissected to determine the effect of the treatments. In 1957 the first generation treatments were applied on June 26 or when 40 per cent of the plants exhibited leaf damage. At that time corn plants were in the whorl stage and approximately 50 inches in extended height. Second generation applications were made on August 4 in 1956 and August 8 in 1957. An experimental fluted-feed granular applicator (Lovely _et al_. 1956) was used to apply the insecticides.

The results of the treatments were evaluated by dissecting 10 corn plants taken at random from the two center rows of each plot. This was done when the majority of the larvae were in the fifth instar. Data were recorded on the number of cavities and the number of living larvae in each plant. The data were then evaluated statistically to determine if differences significant at the 5 per cent probability level existed.

Table 1. Effect of the particle number of granular bentonite and attapulgite impregnated with DDT on control of the second generation European corn borer in 1956.

Carrier	Toxicant per acre (lbs.)	Granules per acre (lbs.)	Particles per acre (million)	Larvae per 100 plants	Per cent reduction
Attapulgite	0.5	5	61.5	128	55
Bentonite	0.5	10	59.0	90	68
Attapulgite	1.0	10	123.0	110	61
Bentonite	1.0	20	118.0	150	47
Untreated				283	

Table 2. Effect of the particle number of granular vermiculite and attapulgite impregnated with endrin on control of the second generation European corn borer in 1956.

Carrier	Toxicant per acre (lbs.)	Granules per acre (lbs.)	Particles per acre (million)	Larvae per 100 plants	Per cent reduction
Attapulgite	0.2	20	246	78	81
Vermiculite	0.2	10	275	78	81
Attapulgite	0.4	20	246	80	80
Vermiculite	0.4	10	275	105	74
Untreated				408	

RESULTS OF 1956

There were five experiments conducted in 1956 which were of questionable value due to the low borer populations. This may have been due to a prolonged egg deposition period, lack of fecundity among the female moths, or the drought conditions prevailing in the area. However, they did indicate the trend which was shown more clearly in the 1957 experiments. For this reason, the experiments on second brood alone will be discussed, the first two of which duplicate experiments conducted on the first generation.

A granular formulation of 10 per cent DDT on attapulgite was applied at 5 and 10 pounds per acre while 5 per cent DDT on bentonite was applied at 10 and 20 pounds. The low and high rates for each formulation

Table 3. Effect of the particle number of granular attapulgite, bentonite, and vermiculite impregnated with DDT on control of the second generation European corn borer in 1956.

Carrier	Toxicant per acre (lbs.)	Granules per acre (lbs.)	Particles per acre (million)	Larvae per 100 plants	Per cent reduction
Vermiculite	0.5	2.5	68.75	128	50
Attapulgite	0.5	5	61.5	103	60
Bentonite	0.5	10	59	78	69
Vermiculite	1	5	137.5	103	60
Attapulgite	1	10	123	68	73
Bentonite	1	20	118	65	75
Vermiculite	2	10	275	85	67
Attapulgite	2	20	246	60	76
Bentonite	2	40	236	50	80
Untreated				255	

were equal to 0.5 and 1.0 pound of DDT and approximately 60 million and 120 million particles per acre respectively. This experiment is summarized in Table 1. The lower particle level gave 55 per cent and 61 per cent control for attapulgite and bentonite respectively. At the higher particle level, attapulgite gave 68 per cent control and bentonite 47 per cent. At the higher particle level attapulgite gave numerically better control than bentonite but statistical analysis indicated no difference between carriers.

The next experiment, which is summarized in Table 2, shows similar results comparing attapulgite with vermiculite both being impregnated with endrin to obtain 0.2 and 0.4 pound of toxicant per acre at one particle level per acre. One and 2 per cent endrin on attapulgite at 20 pounds per acre and 2 and 4 per cent on vermiculite at 10 pounds per acre were used to obtain the two rates. These treatments reduced the infestation from 74 to 81 per cent but there were no significant differences between the treatments.

Table 3 summarizes an experiment in which vermiculite, attapulgite, and bentonite were compared at approximately 62, 125, and 250 million particles per acre. The rates of DDT were equal for each particle level. The analysis of variance indicated that all treatments significantly reduced the infestation and that there were significantly fewer larvae recovered from plots treated with attapulgite and bentonite than in those treated with vermiculite. This could be due to the relatively rapid breakdown of attapulgite and bentonite in water which thereby releases the toxicant more rapidly than the platelets of vermiculite. On a numerical basis the highest particle level gave slightly better control than the two lower levels but the high level also applied considerably more actual DDT. This would suggest that the rate of toxicant is the controlling factor even though it is rather slight in this case.

Table 4. Effect of the particle number of granular attapulgite, bentonite, and vermiculite impregnated with DDT on the control of the European corn borer in 1957.*

Carrier	Granules per acre (lbs.)	Particles per acre (million)	First generation larvae per 100 plants	Per cent reduction	Second generation larvae per 100 plants	Per cent reduction
Vermiculite	3	82.5	370	35	170	53
Attapulgite	6	73.8	273	52	98	73
Bentonite	12	70.8	195	66	110	69
Vermiculite	6	165	283	51	160	55
Attapulgite	12	147.6	315	45	143	60
Bentonite	24	141.6	258	55	125	65
Untreated			573		358	

*DDT applied at the rate of 0.5 pound of actual toxicant per acre.

RESULTS OF 1957

The environmental conditions of 1957 were more nearly normal than those of 1956 and the infestation was much heavier. Therefore, it was thought that these six experiments yielded better indications of the trend which has already been demonstrated concerning the effect of particle numbers on the efficiency of the toxicant.

The data from two experiments comparing the three carriers at approximately 74 and 148 million particles per acre applying 0.5 pound of DDT per acre as a common toxicant are summarized in Table 4. No statistical differences were indicated between treatments. It may be noted that at the lower particle level, vermiculite gave extremely poor control but at the higher level gave control about equal to the other carriers.

Table 5 presents the data obtained from a similar experiment in which endrin at 0.25 pound and toxaphene at 0.75 pound per acre were used as common toxicants. These treatments actually repeat those of the previous test except that different toxicants were used. This was done to test whether differences in control due to particle numbers might be enlarged if endrin or toxaphene were used as common toxicants. The only significant difference was that toxaphene at 0.75 pound gave poorer control than 0.25 pound of endrin per acre. It should be pointed out that toxaphene was applied at a lower rate than that recommended for European corn borer control. Vermiculite as a carrier again gave slightly poorer control. Particles per acre at the two levels did not affect control as has been indicated in the other experiments noted here.

Table 6 summarizes experiments to study the effect of rates of application of DDT and granular carrier on control of the first and second generation European corn borer. The treatments applied in the first

Table 5. Effect of the particle number of granular attapulgite, bentonite, and vermiculite impregnated with toxaphene and endrin on the control of the European corn borer in 1957.

Carrier	Granules per acre (pounds)	Particles per acre (million)	Endrin		Toxaphene	
			Larvae per 100 plants	Per cent reduction	Larvae per 100 plants	Per cent reduction
			First generation			
Vermiculite	5	137.5	75	89	245	63
Attapulgite	10	123	65	90	185	72
Bentonite	20	118	75	89	200	70
Vermiculite	10	275	98	85	383	43
Attapulgite	20	246	--	--	215	68
Bentonite	40	236	53	92	163	76
Untreated			670			
			Second generation			
Vermiculite	5	137.5	150	67	233	49
Attapulgite	10	123	118	74	143	69
Bentonite	20	118	103	78	160	65
Vermiculite	10	275	120	74	263	43
Attapulgite	20	246	--	--	235	49
Bentonite	40	236	110	76	228	50
Untreated			460			

Table 6. Effect of rates of application of DDT and granular carrier on control of the European corn borer in 1957.

Per cent formulation	Granules per acre (pounds)	Actual DDT per acre (pounds)	Larvae per 100 plants	Per cent reduction
		First generation		
1.4	48	.67	80	77
	24	.34	105	70
	12	.17	115	67
3.6	24	.86	98	72
	12	.43	140	60
	6	.22	208	41
7.6	12	.91	55	84
	6	.46	148	58
	3	.23	150	58
Check			353	
		Second generation		
3.6	40	1.44	123	65
	20	.72	203	43
	10	.36	208	41
7.6	20	1.52	123	65
	10	.76	218	38
	5	.38	178	50
17.7	10	1.77	128	64
	5	.89	228	36
	2.5	.44	198	44
Check			353	

generation were 12, 24, and 48 pounds per acre of a 1.4 per cent granular DDT; 6, 12, and 24 pounds of 3.6 per cent granular DDT; and 3, 6, and 12 pounds of 7.5 per cent granular DDT. A similar experiment was conducted on the second generation. The results of the first generation experiments showed that 0.6 pound of actual DDT in granular formulation was too low to give good corn borer control. Therefore, the rates tested on the second generation were increased to 10, 20, and 40 pounds of 3.6 per cent granular DDT; 5, 10, and 20 pounds of 7.6 per cent granular DDT; and 2.5, 5, and 10 pounds of a 17.7 per cent granular DDT. In both experiments the highest levels of each formulation gave significantly better control than the two lower levels. The results of these experiments indicate that the amount of actual toxicant per acre determines the control that can be obtained and the amount of carrier does not affect the control.

REFERENCES

Cox, H.C., T.A. Brindley, W.G. Lovely, and J.E. Fahey. 1956a. Granulated insecticides for European corn borer control. Jour. Econ. Ent. 49:113-119.

______, Lovely, W.G. and T.A. Brindley. 1956b. Control of the European corn borer with granulated insecticides in 1955. Jour. Econ. Ent. 49:834-838.

Fahey, J.E., H.W. Rusk, and H.C. Cox. 1956. Residues on plants treated with DDT granules and emulsions for European Corn borer control. Jour. Econ. Ent. 49:846-849.

Lovely, W.G., H.C. Cox, and T.A. Brindley. 1956. Application equipment for granulated insecticides. Jour. Econ. Ent. 49:839-846.

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A PROPORTIONING FURNACE TEMPERATURE CONTROLLER[1]

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ABSTRACT

An electronic device has been developed which detects changes in furnace temperatures by means of a sensitive resistance element which may be an integral part of the furnace. This element is part of a bridge circuit supplied by a stabilized 1000 cps oscillator. There is a unique temperature for any balance point of the bridge. Any signal due to bridge unbalance is amplified by a high gain, narrow band voltage amplifier. The amplifier output is detected by a phase sensitive detector which controls a dc power amplifier. The power amplifier output controls the current in the dc winding of a saturable core reactor which is in series with the line and the furnace heater windings. The system functions in such a way as to anticipate changes in temperature and proportionately correct the power input to the heater winding. Extensive performance tests in the temperature range 100-700°C have been made and control has been maintained to less than $\pm$ 0.1°C for periods as long as 48 hours. Operation within this limit for longer periods of time depends only upon evaporation or oxidation of the temperature sensitive elements. This is negligible for Pt up to 700°C and for Ni, Alumel, and Hytempco up to 500°C.

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Experiments in this Laboratory with solid-gas reactions and solid-gas equilibria have demanded a reliable temperature controller, adaptable to tube furnaces, which would maintain temperatures constant to $\pm$ 0.1°C or less over a range of 100 to 700°C. Several devices have been used[2] but were discarded because of their unsatisfactory operation over long periods of time or because they were not sufficiently sensitive for our application. A furnace temperature controller has been developed which satisfactorily fulfills our requirements. This is an electronic device which uses a resistance sensing element and operates in an essentially stepless manner involving no on-off relay cycling.

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[1]Contribution No. 669.

[2]Brown Electronik Circular Scale Electric Proportioning Controller with M-H Relay and Class 80 Motor operating a 5-amp autotransformer, The Brown Instrument Company, Philadelphia, Pennsylvania; R. S. Barnes, Jour. Scientific Instruments 28:89-92. 1951.

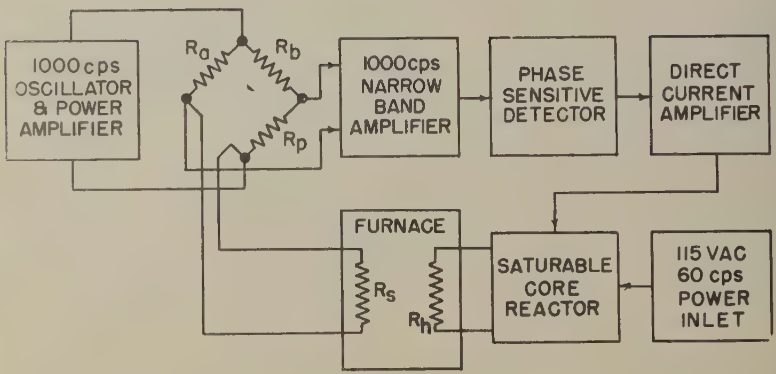

Fig. 1. Block diagram of furnace-temperature controller.

A block diagram of the temperature controller is shown in Fig. 1. The power input to the furnace is regulated by controlling the voltage across the furnace heater winding by means of a saturable core reactor in series with the heater. The temperature sensing element consists of a length of high temperature coefficient resistance wire wound directly on the furnace core alongside the heater winding. This was accomplished by use of either double screw-form ceramic cores or by insulating the heater and sensing wire with small fish-spine insulators[1] and then winding the wire in alternate coils on a stainless steel or an inconel tube. Chromel[2], Nichrome V[3], and Kanthal A[4] have been used as heater windings. Platinum, nickel, Hytempco[3], and Alumel[2] wires have been used for the temperature sensitive windings.

The resistance of the sensing winding, R_s constitutes one leg of a Wheatstone bridge. A second leg consists of a potentiometer R_p and the third and fourth legs of the bridge are fixed resistors, R_a and R_b. All bridge components with the exception of the sensing element are of resistance materials having low temperature coefficients. For any setting of R_p there is a unique temperature at which the bridge will be balanced. With an ac voltage impressed across the bridge, a variation in the temperature from one side of the balance point to the other causes the bridge output voltage to pass through a null while it changes phase by 180°. The out-of-balance signal is fed into a narrow-band amplifier and then into a phase-sensitive detector. The output of the detector is either a positive or negative dc voltage depending upon which side of the null the unbalancing of the bridge occurs. The phase detector output is connected

[1] Leeds and Northrup, Philadelphia, Pennsylvania, Cat. No. STD 715-B.
[2] Hoskins Manufacturing Company, Detroit 8, Michigan.
[3] Driver-Harris Company, Harrison, New Jersey.
[4] The C.O. Jeliff Mfg. Corp., Southport, Connecticut.

to a dc power amplifier which controls the series impedance of the saturable core reactor. When proper phase and polarity connections are maintained, control of the input power to the furnace heater winding by the reactor serves to control the temperature of the furance. Any change in the temperature unbalances the bridge in such a way as to increase or decrease the heater voltage in the direction necessary to offset the original variation. The degree of temperature change is sensed and proportionately compensated by the change in the heater winding voltage. When the potentiometer position is changed, the bridge is unbalanced and the control system either increases or decreases the heater voltage until bridge balance is again attained at a new temperature and a new value of sensing element resistance.

This temperature controller has been tested under a number of conditions. A standard platinum resistance thermometer placed within the furnace tube has also been successfully used as the sensing element. Over a temperature range of 100 to 700°C, temperature control to within $\pm$ 0.1°C has been attained for periods as long as 48 hours.

A complete schematic diagram of the controller circuit is shown in Fig. 2. The 1000 cps voltage for the bridge and phase detector reference is supplied by a parallel-tee feedback oscillator driving a 6V6, class Ab_1, push-pull power amplifier. Two plate transformers are provided for the power amplifier. One is employed in a normal push-pull manner and the second is connected plate-to-plate as indicated in the figure. The exact frequency of the oscillator is not important; however, to prevent beat frequency difficulties, caution should be taken to ensure that the system frequency is not a harmonic of the power line system.[1]

For greater sensitivity of control the adjustable leg of the Wheatstone bridge may consist of a potentiometer connected between and in series with two fixed resistors. Values for these resistors depend upon the residual resistance of the temperature sensing element at ambient room temperatures and by the expected variation in value of the resistance of the sensing element over the intended operation range. For circuits that are to be used with a variety of furnace designs, these resistors may be omitted as in Fig. 2. When this is done, however, a portion of the active control region of the potentiometer is sacrificed.

Basically the amplifier is a "starved" amplifier[2] with a cathode follower output. Narrow band characteristics of the amplifier depend upon the parallel-tee network as the feedback element. The amplifier gain is approximately 80,000 without feedback. Since a small amount of ac feedback accompanies the dc feedback, the ac gain without the parallel-tee network is connected between the output of the second amplifier stage and to the input of the cathode follower. Because it is difficult to null a parallel-tee network to better than 1 part in 250 without excessive manipulation and the availability of a harmonic free test signal, some ac feedback occurs at the null frequency which further reduces the over-all amplifier gain. In the case of this amplifier the actual gain is reduced to about 10,000. Improper alignment of the parallel-tee network will

[1]The 1020 cps component of most 60 cps ac power systems which is due to commutator-slot ripple should be avoided.

[2]Volker, W.K., Electronics 24(3):126-129. 1951.

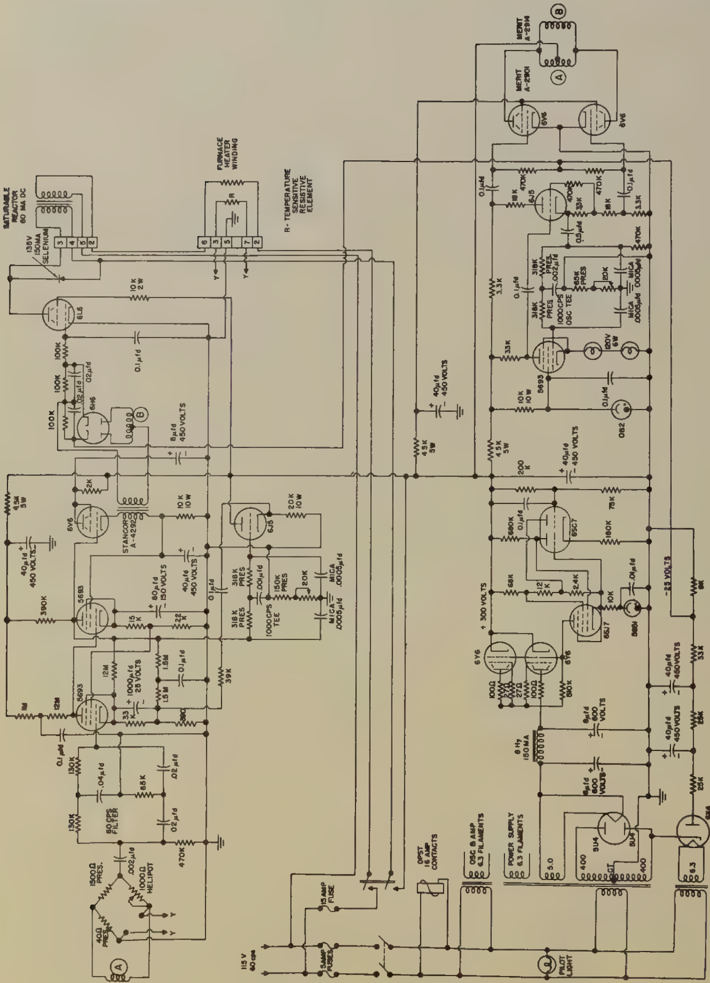

Fig. 2. Schematic Diagram of Furnace-Temperature Controller.

very easily cause an amplifier of this type to oscillate at a frequency near the null frequency of the network. Because of improper alignment, the output at some frequency near the true null frequency can have a component which is 180° out of phase with reference to the input of the parallel-tee network. Since the feedback is already negative, this additional phase shift can bring the total phase shift to 360°, making the over-all system oscillatory. In aligning a parallel-tee for use in a circuit such as this, it is best to leave the null slightly on the side having zero phase shift between the output and input. In case of doubt concerning the exact null point due to harmonic distortion of the test signal, an output should be accepted which, although not exactly a voltage null, has a zero phase shift at the central frequency and less than 90° lead or lag for all other frequencies.

The output signal from the amplifier and cathode follower goes to the phase detector where the signal is compared with the reference phase to produce a dc output voltage. The polarity and magnitude of this output controls the 6L6 power amplifier which regulates the current in the dc winding of the saturable core reactor. Current in this winding controls the impedance between the power line and the furnace windings. Hence a signal from the unbalanced bridge due to a temperature error serves to control the power to the furnace. When proper phase and polarity connections are maintained this system serves as a temperature controller that proportionately corrects for temperature variations of any magnitude.

Due to the high gain amplifier, noise pickup becomes critical and every effort should be made to minimize it, especially at the bridge frequency. As an aid to noise reduction, as many leads as possible in the oscillator, power amplifier, and narrow band amplifier should be decoupled. Even with this decoupling, a considerable noise signal may be induced at the input to the narrow-band amplifier. This may be of appreciable magnitude but is induced with a phase angle of nearly 90° with respect to the reference phase. Thus, only a small component of the noise is in phase with the error signal from the bridge and therefore the effect on the operation of the controller is negligible.

In most of the furnaces used with this controller, the heater and sensing windings are separated by a very short distance. However, because of the thermal lag in the heater winding, in the heater core, in the sensing element and in the saturable core reactor, the over-all system does not actually behave as smoothly as indicated above. The various lags are such that the input power tends to overheat the heater windings. This causes the sensing element to overheat also, causing the furnace power to be reduced too much. The temperature then drops. The sensing element detects this drop in temperature and causes the heater power to increase and thus the system continuously "hunts" for a stable operating point. The period of this "hunting" varies from furnace to furnace but is generally very short. In these cases the entire system behaves as a very fast cycling device. The cycling is so rapid that the heat capacity of the core smooths out temperature cycling in the furnace to less than $\pm$ 0.1°C. Generally, metal-tube furnace cores minimize the tendency of the circuit to hunt. Some experience has been had with large heat capacity furnaces containing salt baths in which control to $\pm$ 0.02°C at 360° has been maintained for several hours.

The present model of this controller has been constructed in such a way that any 60 ma saturable core reactor may be used, thereby making the system adaptable to any furnace temperature control problem for which a suitable reactor, in terms of power handling, is available. The bridge parameters given in Fig. 2 are suitable for any sensing element having a room temperature resistance of 10 to 12 ohms and is one of the metals or alloys specified above, or any other metals or alloys having similar thermal coefficients of resistivity.

Careful measurement was made of temperature fluctuations in a small, metal-core tube furnace used in actual experiments. The sensing element was a platinum wire, insulated by 0.110-inch diam. fish-spine insulators and having a cold resistance of 10 ohms. The heater was of Chromel A with a cold resistance of 25 ohms. A 2 KVA saturable core reactor was used. Temperatures were measured by a Chromel-Alumel (AWG No. 26) thermocouple held against the furnace wall by means of a Vycor tube. The bridge was adjusted so that the furnace temperature would be approximately 500°C. A potentiometer-galvanometer system sensitive to 2 μv was used to monitor the thermocouple voltage. Variation observed at the control temperature was $\pm$ 2 μv over a six-hour period. During this test, the temperature remained constant at the furnace wall within a range of less than 0.1°C and no temperature drift was observed.

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AN APPLICATION OF PROGRAMMING IN TESTING EFFICIENCY OF LEASING SYSTEMS[1]

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Tenure and leasing studies of farms have been an important area of institutional economics. Similarly, as an institution, tenure has an important impact on resource use and income distribution. In this study we attempt to analyze certain leasing institutions by means of linear programming techniques. Our procedure is to start with a typical rented farm in Iowa. We then analyze some common leasing arrangements to determine whether optimum plans determined by this procedure are consistent between tenant and landlord. In other words, we take the leasing arrangement for either party and work out separate plans for the tenant and the landlord. Either plan is one which will maximize profits for the particular individual, given his fixed resources and the restraints which the leasing arrangement places on his share of inputs and outputs. If the plan which maximizes profit for the tenant provides an organization for the farm which is identical with that for the plan which maximizes profit for the landlord, we have determined a consistent leasing system. However, if the profit maximizing tenant plan gives an organization differing from that for the profit maximizing landlord plan, tenure conflict still remains and various types of bargaining procedures may be required to resolve the situation.

LOCATION AND DESCRIPTION OF THE FARM

The present study deals with a farm located on Clarion-Webster soil, in Hardin County, Iowa. Table 1 provides the basic restraints, other than capital, used in programming the farm. Adequate grain storage facilities and machinery are available.

Enterprises

Previous studies indicate that only the three crop rotations used as activities in this study ordinarily enter into the most profitable farm plans for the soil area: corn-corn-soybeans rotation (CCSb), corn-soybeans-corn-oats-meadow rotation (CSbCOM) and corn-corn-oats-meadow rotation (CCOM). Four fertilization levels are considered for each rotation. Hereafter, fertilization levels for a given rotation are noted by a subscript following the abbreviated form of the rotation (e.g., $CCSb_1$, $CCOM_4$, $CSbCOM_3$). The possibilities of these several rotations

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[1]Journal Paper No. J-3365 of the Iowa Agricultural and Home Economics Experiment Station. Project No. 1328.

Table 1. Selected resource restraints for farm studied.

Resource restraint	Amount
Tillable acres	153
Cattle housing space (sq. ft.)	1,176
Hog farrowing space (sq. ft.)	364
Labor (man-hours):	
January	275
February	275
March	335
April	350
May	350
June	350
July	350
August	350
September	300
October	300
November	275
December	275
Machinery available	adequate

and fertilization levels are used to determine such things as: a) whether a landlord with limited capital prefers a grain rotation while a tenant with ample capital prefers a forage rotation for livestock; b) whether a landlord with ample capital prefers a heavy level of fertilization while a tenant with limited funds prefers a low level of fertilization with part of his capital invested in livestock; c) whether the method of sharing fertilizer costs and crop returns affects the level of fertilization desired by each party.

Three livestock activities are considered in the study and include the most profitable hog system and cattle feeding programs for average conditions (determined from previous studies). Livestock enterprises are included to determine

1. Whether situations exist where the tenant under a crop-share lease would prefer to invest in livestock and accompanying rotations, rather than a fertilization plan and cropping system which is optimum for the landlord, and
2. If a shift from a crop-share to a livestock-share lease causes the same plan to be optimum for the tenant and landlord.

The livestock activities are

1. A two-litter hog system,
2. Pasture-fed steer calves, and
3. Deferred-fed steer calves.

CAPITAL LEVELS AND COSTS

The optimum farm plans for the landlord and tenant are expected to vary considerably with different levels of available capital. Four capital levels for paying farm expenses are assumed for the landlord: $500, $1,200, $2,000 and unlimiting capital. Only two capital levels for paying farm expenses are considered for the tenant: $3,000 and $10,000.

TYPES OF LEASES

Outlined below are the terms of the different leases considered in the study. Optimum plans are computed for each of the leasing situations with various combinations of capital levels for the tenant and the landlord[1] (see Table 2 for the combinations of capital situations under one lease). Of the crop-share leases considered, lease A_1 is the most prevalent or typical crop-share arrangement existing in the areas. Leases A_3 and A_4 are variations of the typical crop-share lease (A_1); these leasing variations are also frequently used in the areas studied. Crop-share leases A_2, A_5, and A_6 are leasing arrangements which have been suggested as possible alternatives to existing crop-share leases. The typical or "most common" livestock-share lease is considered to determine whether a consistent optimum plan can be determined under this leasing arrangement when a crop-share lease does not lead to consistent plans.

Crop-Share Leases

A_1 Typical crop-share lease

Item	Receipts or expenses (%) Tenant share	Landlord share
Corn	50	50
Soybeans	50	50
Oats	60	40
Fertilizer and seed expenses[2]	50	50
Operating expenses	100	0
Real estate expenses	0	100
Labor, including hired	100	0
Feeder cattle and hogs (receipts and expenses)	100	0

Cash rent on hay and rotation pasture land[3]

[1]In other words, two sets of plans (one set for the tenant and one for the landlord) have been worked out by the linear programming technique for each combination of capital situations under each lease arrangement.

[2]Landlord furnishes all of the grass and legume seed while tenant furnishes all of the seed oats.

[3]Cash rents on hay of $10, $16, and $25 per acre are studied.

A_2 Same as A_1 except that, for each rotation and fertilizer level the landlord receives a sufficiently large cash rent on hay and pasture land to give him a return equal to that received from his most profitable rotation (where the capital of the landlord is not limiting).

A_3 Same as A_1 except that the tenant pays all fertilizer and seed expenses.

A_4

Item	Receipts or expenses (%) Tenant share	Landlord share
All grain crops	50	50
Value of hay or pasture[1]	50	50
Fertilizer and seed expenses	50	50
Operating expenses (including hired labor)	50	50
Real estate expenses	50	50
Labor (operator labor)	100	0
Feeder cattle and hogs (receipts and expenses)	100	0

A_5 Same as A_1 except that the landlord allows no livestock production by the tenant.

Typical Livestock-Share Lease

Item	Receipts or expenses (%) Tenant share	Landlord share
Livestock receipts	50	50
Investment in livestock and livestock equipment	50	50
Livestock expenses	50	50
Crop receipts (if any)	50	50
Fertilizer and seed	50	50
Operating expenses (including hired labor)	100	0
Real estate expenses	0	100
Labor (operator)	100	0

In programming optimum plans for the tenant, we have, for both tenant and landlord, the usual profit maximizing equation $z = C'X$ where z is profit, C is a vector of market prices for the products which either party sells and X is a vector of activity levels for either party. Of course, a separate plan is worked out for the two, with the plans being in conflict if the two X vectors differ. The plans are the same and are consistent if the two separately determined X vectors, for the final

[1]It is assumed that the tenant purchases the landlord's share of the hay and pasture at the market price for hay.

programs, are identical. For both parties, profit maximizing plans are computed subject to the restraints

$$AX \leq S$$

where A is the matrix of input coefficients, representing the shares of resources furnished by each party to provide one unit of output for himself while S if the vector of limited resource for each party.

ANALYSIS OF RESULTS

This section presents the most profitable farm plans, as determined by the linear programming technique, for the landlord and tenant under various leasing and resource situations. Major emphasis is placed upon the conflict of interests or divergence of plans which arise between landlord and tenant because of leasing restrictions and capital limitations.

Crop share lease A_1

Lease A_1 is the typical crop-share lease outlined earlier. In the discussion which follows, a cash rent of $10 per acre is assumed for hay and rotation pasture land. The results of increasing the cash rental to $16 and $25 per acre also are presented.

Table 2 summarizes the most profitable landlord and tenant plans under typical crop-share lease A_1 for various combinations of landlord and tenant capital levels. The plans presented in Table 2 are based on a $10 per acre cash rent on hay and rotation pasture. With very limited capital ($500 under A and B in Table 2) for crop-share lease A_1, the landlord would be unable to pay his share of the expenses necessary for planting the entire farm in a crop rotation. Therefore, he would find it most profitable to select the rotation and the fertilizer level which gives him the highest return per dollar invested. Accordingly, the landlord's optimum program would be 130 acres of CCSb without fertilizer ($CCSb_1$) with 23 acres remaining in disposal (hay or pasture land seeded in a previous year).

The tenant's most profitable program with $3,000 capital (A in Table 2) is 147 acres of $CCSb_3$. Thus, when the tenant has $3,000 and the landlord has $500 to invest in the year's cropping program (A in Table 2), the same rotation is optimum for the two but a difference arises in the level of fertilization which is optimum. The landlord "prefers" the first level of fertilization (no commercial fertilizer) while the tenant "prefers" the third level.

It may at first appear to be more profitable for the tenant, as would be the case for an owner-operator with very limited funds, to plant the entire 153 crop acres to CCSb and fertilize some of the acres at a rate lower than the third level. However, the tenant's position can be explained as follows: Under the typical crop-share lease the tenant pays 50 per cent of the fertilizer cost and receives 50 per cent of the increase in crop yields; he pays 100 per cent of the operating expenses (except seed) needed for growing the crops, but receives only 50 per cent of the crop yields. Therefore, the tenant received a relatively high return on fertilizer as compared with the return from growing the crops.

Table 2. Most profitable landlord and tenant programs under typical crop-share lease A_1[a], with various levels of landlord and tenant capital.

Party	Capital level[b] (dollars)	Acres of rotation: $CCSb_1$	Acres of rotation: $CCSb_3$	Acres of rotation: $CCOM_3$	Acres of rotation: $CSbCOM_3$	Disposal land	Tenant's livestock program: Calves (no.)	Tenant's livestock program: Hogs (litters)	Return (dollars)
A (Landlord	500	130	---	---	---	23	---	---	2, 854
(Tenant	3, 000	---	147	---	---	6	---	---	2, 242
B (Landlord	500	130	---	---	---	23	---	---	2, 854
(Tenant	10, 000	---	15	6	132	---	40	10	4, 397
C (Landlord	1, 200	---	153	---	---	---	---	---	4, 331
(Tenant	3, 000	---	147	---	---	6	---	---	2, 242
D (Landlord	1, 200	---	153	---	---	---	---	---	4, 331
(Tenant	10, 000	---	15	6	132	---	40	10	4, 397
E (Landlord	2, 000	---	153	---	---	---	---	---	4, 331
(Tenant	3, 000	---	147	---	---	6	---	---	2, 242
F (Landlord	2, 000	---	153	---	---	---	---	---	4, 331
(Tenant	10, 000	---	15	6	132	---	40	10	4, 397
G (Landlord	Unlimiting	---	153	---	---	---	---	---	4, 331
(Tenant	3, 000	---	147	---	---	6	---	---	2, 242
H (Landlord	Unlimiting	---	153	---	---	---	---	---	4, 331
(Tenant	10, 000	---	15	6	132	---	40	10	4, 397

[a] With $10 per acre cash rent on hay and rotation pasture.
[b] Capital available for use in the farm business.

This reasoning shows why the tenant with very limited capital maximizes his net return by using his limited capital in applying heavier rates of fertilizer and planting fewer acres (A in Table 2). Conversely, this same reasoning shows why the landlord, if he is to maximize profits, should reject fertilizer use until the more profitable alternative of putting the entire farm into rotation has been exploited. The landlord pays little of the cost but gets half the product in the normal field operations in growing crops; he receives half of the yield increase from fertilizer but also must pay half of the cost of fertilizer. (The landlord's share of the seed is far less than half the cost of growing the crops.)

When the landlord's capital is increased to $1,200 or more, his most profitable plan is $CCSb_3$ for the entire farm (C through H in Table 2). The landlord maximizes profits by specifying the CCSb rotation because it has a higher per-acre net return than the CSbCOM and CCOM rotations when cash rent on hay is $10 per acre. Relatively lower incomes for the landlord from the meadow rotations can be attributed primarily to (a) the presence of oats (a low income crop) in the rotation and (b) a low return on hay when it has a cash rent of only $10 per acre. Fertilizer use is not extended beyond the third rate, because the added cost of the fourth rate of fertilizer is greater than the added returns from the increased yields under the price relationships used. Decreasing net returns for the fourth fertilizer rate are found for all three rotations.

A greater conflict in optimum plans arises when the tenant's capital is increased to $10,000 and the landlord's capital for annual expenses remains at $500 (B in Table 2). Whereas the optimum cropping program is 130 acres of $CCSb_1$ for the landlord, it is primarily $CSbCOM_3$ for the tenant. The tenant's most profitable plan with $10,000 capital includes a large proportion of the meadow rotations to support a sizeable livestock program (B in Table 2). From the tenant's standpoint, the capital requirements and the net returns per acre of the meadow rotations with livestock are higher than the capital requirements and the net returns per acre from cash crop rotations such as CCSb. Returns per dollar invested, however, are highest under the CCSb cash crop rotation.

As noted earlier, with only $3,000 capital (A in Table 2) the tenant engages in the CCSb rotation where returns on capital are highest. With $10,000 capital (B in Table 2), however, the tenant maximizes his overall return (i.e., to both capital and labor) by investing in livestock and meadow rotations, even though these activities bring lower returns on capital then the CCSb rotation. Hence, if the landlord specifies the optimum program for himself under B in Table 2, it will depress profits to the tenant who needs meadow for his livestock. Similarly, if the tenant specifies his optimum program, it will depress profits to the landlord who receives a low return on the hay produced.

When the capital of the landlord is increased to $1,200 and the capital of the tenant is restricted to $3,000 (C in Table 2), the cropping and fertilization plan for the two parties are almost identical. The landlord's greater funds allow him to invest in the third level of fertilization; the tenant's restricted capital position causes a cash crop rotation with a high level of fertilization to be more profitable than a forage rotation for livestock. However, an increase in the tenant capital level to $10,000 while the landlord capital level remains at $1,200 causes the optimum

plans (D in Table 2) to again diverge: it becomes more profitable for the tenant to use a forage rotation which can be converted to a greater return through livestock; the landlord maximizes profit with heavy fertilization of a strictly grain rotation, since he does not gain from conversion of forage to livestock products. Similarly, when the tenant has limited capital while the landlord has unlimiting capital (G in Table 2), the two plans are again quite parallel. However, as the tenant's capital is increased to $10,000 (H in Table 2), the plans of the two parties again become divergent.

Differentials, then, in relative amounts of capital for tenant and landlord under a crop-share lease can cause optimum plans for the two parties to be quite different. It is apparent from Table 2 that the tenant and landlord programs are most nearly parallel when the tenant is limited to $3,000 capital while the landlord has $1,200 or more of capital (C, E and G in Table 2). The most serious conflict of interests occurs when the landlord has only $500 capital while the tenant has $10,000 capital (B in Table 2). Hence, it appears that, unless landlord and tenant have approximately the same relative capital limitations, a crop-share lease cannot be found which gives a single best plan for both leasing parties and for the farm.

The above plans have been computed for a typical crop-share lease with a $10 per acre cash rent on hay and rotation pasture. Since considerable variation in hay rentals may be found in the area studied, optimum plans (not presented) also were computed for a typical crop-share lease with the hay rent increased to $16 and $25 per acre. The optimum landlord and tenant plans were exactly the same for a crop-share lease with $16 and $25 per acre cash rent on hay and pasture. These plans also differed only slightly from the optimum plans for each party when the rent was $10 per acre. The $25 hay rental was still too low to discourage the tenant from entering into a livestock program built around a meadow rotation; it was also too low to induce the landlord to change from CCSb to a meadow rotation.

Crop-share lease A_2

Increasing the cash rent on hay and pasture to $25 per acre does not cause the landlord and tenant plans to be consistent under a crop-share lease where the tenant receives the full return from livestock. Hence this question arises: What level of cash rent will cause a meadow rotation, which is best for the tenant's livestock program, to be most profitable for the landlord who does not realize part of the livestock return? To answer this question, the situations for lease A_2 have been included.

Lease A_2 is a typical crop-share lease with the following important exception: From each rotation and fertilizer level the landlord receives a sufficiently large cash rent on hay and pasture to give him a return per acre of rotation equal to that received from his most profitable rotation (i.e., when the landlord is assumed to have at least $2,000 available for use in the farm business). Lease A_2 is devised to insure that the two leasing parties will find the same plan to be optimum. Regardless of the plan chosen by the tenant, this same plan should be satisfactory to the landlord since he received an equal net return per acre from all rotations and fertilization levels.

Table 3. Most profitable landlord and tenant programs under crop-share lease A_2,* with various levels of landlord and tenant capital.

Party	Capital level** (dollars)	Acres of rotation: $CCSb_3$	Acres of rotation: $CSbCOM_3$	Acres of rotation: Disposal land	Tenant's livestock program: Calves (no.)	Tenant's livestock program: Hogs (litters)	Return (dollars)
A (Landlord	2,000	153	---	---	---	---	4,331
(Tenant	3,000	147	---	6	---	---	2,242
B (Landlord	2,000	153	---	---	---	---	4,331
(Tenant	3,132	153	---	---	---	---	2,333
C (Landlord	2,000	14	139	---	---	---	4,331
(Tenant	10,000	14	139	---	40	10	3,293

*"Typical" crop-share lease except that for each rotation and fertilizer level the landlord receives a sufficiently large cash rent on hay and pasture to give him a return equal to that received from his most profitable rotation ($CCSb_3$).
**Capital available for use in the farm business.

The most profitable rotation for the landlord (when cash rents on hay range from $10 to $25 per acre) is $CCSb_3$. Cash rents on hay ranging from $39.85 to $48.65 per acre are needed to raise the landlord's returns per acre from the meadow rotations to the level of his returns from the $CCSb_3$ rotation.

Table 3 summarizes the most profitable programs for the landlord and tenant at various capital levels under crop-share lease A_2 (typical crop-share lease with equal returns to the landlord from all rotations). With only a $3,000 capital level, the tenant's optimum program is 147 acres of $CCSb_3$ with 6 acres in disposal land, while the landlord's optimum program is 153 acres of $CCSb_3$ (A in Table 3). However, when the tenant's capital level is $3,132 or more (B and C in Table 3), the landlord and tenant can reach complete agreement, i.e., the landlord is indifferent between $CCSb_3$ and any of the meadow rotations (ignoring the slight differences in capital requirements noted above). It is interesting to observe that the tenant's optimum program with $10,000 under lease A_2 (Table 3) differs only slightly from the tenant's optimum program for lease A_1 (Table 2) when the cash rent on hay is only $10 per acre. Apparently the tenant is able to pay a rather high price on hay for the opportunity to engage in livestock enterprises. The acreage of meadow for the tenant's optimum plan with $10,000 under lease A_2 is quite small; approximately 28 acres for a 160-acre farm. The total cash rent required thus would be only about $1,120 for the farm. Many landlords charge this total amount of cash rent for "privilege" rent or as rent on buildings, lots, and hay. Whether the tenant could be induced to pay such a high rental under all conditions is somewhat doubtful.

In interpreting the income figures in all tables, the following point should be remembered: The arrangements examined in this study are in terms of leasing and resource efficiency and not in terms of an equitable

distribution of the income of a particular magnitude. It is possible that the relative income division might be equitable but that the lease is not efficient in terms of the resource conditions. In the case where a new leasing arrangement brings about resource efficiency but distorts the pattern of income division, other adjustments could be made to restore the previous levels of tenant and landlord income.

Crop-share lease A_3

Lease A_3 is a typical crop-share lease except that the tenant pays all fertilizer and seed costs instead of half of the cost of these items. Since this particular cost sharing arrangement is a common variation of the typical crop-share lease, it is examined here to determine the effects upon the optimum plans of the two parties.

Table 4 summarizes the most profitable plans for the landlord and tenant under crop-share lease A_3 (tenant pays all the seed and fertilizer costs) with various levels of capital for the landlord and tenant. A cash rent on hay of $16 per acre is assumed for the plans in Table 4. The landlord's optimum program at all capital levels is now 153 acres of CCSb at the highest rate of fertilization ($CCSb_4$). As noted previously, the added total cost of the fourth level of fertilization is greater than the added total return from the increase in yields. It is, with the prices used, an uneconomic level of fertilization even on an owner-operated farm. However, because the landlord pays no fertilizer or seed expense but receives half of the increase in returns under the present lease, he finds the fourth level of fertilization to be optimum even though this level of fertilization is uneconomic for the farm as a whole.

The tenant's most profitable plan with $3,000 in capital is now 65 acres of $CCSb_1$ and 88 acres of $CCSb_2$ (A in Table 4). When seed and fertilizer expenses are shared 50-50 (see A in Table 2) the tenant finds it most profitable to fertilize fewer acres (147 acres) at a higher rate and leave 6 acres in disposal.

When the tenant's capital is increased to $10,000 under the present lease (e.g., see B, Table 4) his most profitable plan is only slightly different from his optimum plan with $10,000 when fertilizer and seed expenses are divided on a 50-50 basis (see B, Table 2). The major change in the tenant's plan is that fertilizer use now extends only to the first and second levels instead of to the third level of application.

Crop-share lease A_4

Lease A_4 is a crop-share leasing arrangement sometimes suggested as an alternative to the more common crop-share arrangements. Under lease A_4 all crop expense (including operating and building expense) and crop production is divided equally between landlord and tenant. The tenant, however, retains full ownership and responsibility for the livestock enterprises. According to the 50-50 division of the crop, the landlord receives half of the value of the hay and rotation pasture produced. It is assumed that the tenant purchases the landlord's share of the hay and rotation pasture at the market price for hay and uses this roughage in his livestock program.

The major change in the present lease (A_4) from a typical crop-share lease is that operating and building expenses are now divided on a 50-50

Table 4. Most profitable landlord and tenant programs under crop-share lease A_3[a], with various levels of landlord and tenant capital

Party	Capital level[b] (dollars)	Acres of rotation				Tenant's livestock program		Return (dollars)
		$CCSb_1$	$CCSb_2$	$CCSb_4$	$CSbCOM_2$	Calves (no.)	Hogs (litters)	
A (Landlord	500	---	---	153	---	---	---	5,301
(Tenant	3,000	65	88	---	---	---	---	1,452
B (Landlord	500	---	---	153	---	---	---	5,301
(Tenant	10,000	8	---	---	145	38	10	3,743
C (Landlord	1,200	---	---	153	---	---	---	5,301
(Tenant	3,000	65	88	---	---	---	---	1,452
D (Landlord	1,200	---	---	153	---	---	---	5,301
(Tenant	10,000	8	---	---	145	38	10	3,743
E (Landlord	2,000	---	---	153	---	---	---	5,301
(Tenant	3,000	65	88	---	---	---	---	1,452
F (Landlord	2,000	---	---	153	---	---	---	5,301
(Tenant	10,000	8	---	---	145	38	10	3,743
G (Landlord	Unlimiting	---	---	153	---	---	---	5,301
(Tenant	3,000	65	88	---	---	---	---	1,452
H (Landlord	Unlimiting	---	---	153	---	---	---	5,301
(Tenant	10,000	8	---	---	145	38	10	3,743

[a] Typical crop-share lease with $16 per acre cash rent on hay and pasture, except that tenant pays all fertilizer and seed expenses.

[b] Capital available for use in the farm business.

basis between landlord and tenant. Operating expenses are considerably greater than building expenses, hence, there is a shift in total expenses from the tenant to the landlord. Therefore, with very limited capital (\$500, A in Table 5), the landlord's optimum program contains only 43 acres of $CCSb_2$ with 110 acres in disposal land. The landlord does not maximize profits by planting more than 43 acres of CCSb without fertilizer because the initial yield response for fertilizer is high enough to allow a slightly higher return per dollar invested under $CCSb_2$ than under $CCSb_1$. (The "net return/capital requirement" ratio per acre is greater for $CCSb_2$ than for $CCSb_1$.) With an increase in the landlord capital level, more acres are planted to $CCSb_2$ and $CCSb_3$ until, with unlimiting capital, the landlord's optimum program is once again $CCSb_3$ for the entire farm (H in Table 5).

Because of the shift in expenses from the tenant to the landlord under the present leasing alternative (A_4), it is possible for the tenant to plant the entire farm to rotation even with limited capital (\$3,000, A in Table 5). Such a plan for the tenant is not possible under the usual cost-sharing arrangement (see A in Table 2). Also with a high capital level, the tenant is able to produce more acres of the meadow rotations and maintain a larger livestock program than was possible under the common cost-sharing arrangement (compare B, Table 5 and B, Table 2).

The 50-50 method of sharing crop costs and returns (lease A_4, Table 5) is no more successful in reducing leasing frictions than the typical crop-share lease (Table 2). In fact, if the landlord is very limited on capital and the tenant is not, the optimum programs for the two parties are more diverse than under a typical crop lease (compare B, Table 5 and B, Table 2). The shift in expenses toward the landlord does not change the landlord's optimum rotation from CCSb (B in Tables 2 and 5); the increased expense merely permits the landlord to plant a smaller acreage of this rotation. Reduced tenant expenses, on the other hand, allow the tenant to proceed even further in the direction of more m adow in the rotation as a means of obtaining a profitable use of his capital through livestock production (see B in Tables 5 and 2).

Crop-share lease A_5

Under all previous leases the tenant is allowed to operate an independent livestock program. However, in all of the leasing variations examined, changes to cause tenant and landlord production possibilities for crops to be similar does not bring about complete consistency of plans. This is true because differences in production possibilities between crops and livestock are still different for the tenant and landlord, or for each party as compared to the farm as a whole (see discussion under typical crop-share lease A_1). Since the landlord does not realize part of the gain in value of the forage processed through livestock, he gains from a meadow rotation only when hay has a sufficiently high rental or price to cause hay returns to compare favorably with corn and soybeans. In contrast, the tenant realizes full gain from forage for a livestock program and, if he has sufficient capital, maximizes profit with a forage rotation. Hence, crop-share lease A_5, which does not allow livestock, is examined as an alternative to bring about consistency of plans. A cash rent of \$10 per acre on hay is assumed for lease A_5.

Table 5. Most profitable landlord and tenant programs under crop-share lease A_4,[a] with various levels of landlord and tenant capital.

Party	Capital level[b] (dollars)	Acres of rotation: $CCSb_2$	$CCSb_3$	$CSbCOM_3$	$CCOM_3$	Disposal land	Tenant's livestock program: Calves (no.)	Hogs (litters)	Return (dollars)
A (Landlord	500	43	---	---	---	110	---	---	868
(Tenant	3,000	---	149	4	---	---	---	6	3,530
B (Landlord	500	43	---	---	---	110	---	---	868
(Tenant	10,000	---	---	122	31	---	46	10	4,750
C (Landlord	1,200	104	---	---	---	49	---	---	2,082
(Tenant	3,000	---	149	4	---	---	---	6	3,530
D (Landlord	1,200	104	---	---	---	49	---	---	2,082
(Tenant	10,000	---	---	122	31	---	46	10	4,750
E (Landlord	2,000	24	129	---	---	---	---	---	3,372
(Tenant	3,000	---	149	4	---	---	---	6	3,530
F (Landlord	2,000	24	129	---	---	---	---	---	3,372
(Tenant	10,000	---	---	122	31	---	46	10	4,750
G (Landlord	Unlimiting	---	153	---	---	---	---	---	3,430
(Tenant	3,000	---	149	4	---	---	---	6	3,530
H (Landlord	Unlimiting	---	153	---	---	---	---	---	3,430
(Tenant	10,000	---	---	122	31	---	46	10	4,750

[a] Receipts and expenses on all crops divided 50-50 between landlord and tenant.

[b] Capital available for use in the farm business.

Table 6. Most profitable landlord and tenant programs under crop-share lease A_5,[a] with various levels of landlord and tenant capital.

Party	Capital level[b] (dollars)	Acres of rotation CCSb$_2$	CCSb$_3$	Disposal land	Return (dollars)
A (Landlord	1,166	20	133	--	4,224
(Tenant	3,000	--	147	6	2,242
B (Landlord	3,888	--	153	--	4,269
(Tenant	10,000	--	153	--	2,341

[a]Typical crop-share lease with $10 per acre cash rent on hay and pasture, but tenant cannot have livestock.
[b]Capital available for use in the farm business.

Table 6 summarizes the most profitable plans for the landlord and tenant at various levels of capital when the tenant is not permitted to raise livestock. An attempt was made to determine the quantity of capital for the landlord which would give both parties the "same relative capital limitations" based on the $3,000 and $10,000 tenant capital levels. The procedure for arriving at these figures consisted of (1) computing a ratio between the landlord and tenant capital requirements for each activity (only nonlivestock activities were included in these computations), then (2) multiplying the simple mean of these ratios by each of the tenant's capital levels ($3, 000 and $10, 000) to obtain the two capital figures for the landlord. The computed capital levels for the landlord are shown in A and B, Table 6.

When the alternative of raising livestock is omitted from farm planning, neither the landlord nor the tenant find it profitable to include meadow in the rotation. Though the CCSb rotation is now most profitable for both parties at all capital levels, the specialized sharing of resources (such as labor and machinery) still prevents complete agreement on fertilization rates (see A in Table 6). The tenant, because he has a relative advantage in fertilizer use, maximizes his profits by fertilizing 147 acres at the third level with 6 acres in disposal. The landlord, of course, maximizes his profits by having the entire farm in rotation and fertilizing to the limits of his capital. Hence, the landlord and tenant cannot reach complete agreement upon an optimum program (even without livestock) until both parties have enough capital to plant the entire farm to CCSb$_3$.

Typical Livestock-Share Lease

Under the typical livestock-share lease, all livestock investment, expenses, and returns are shared equally between the landlord and tenant. However, the tenant furnishes all machinery and pays the operating expenses while the landlord pays all real estate expenses. The livestock-share lease is included as a possible basis for consistency of plans since the following has been apparent throughout the analysis: The

Table 7. Most profitable landlord and tenant programs under a typical livestock-share lease,[a] with various levels of landlord and tenant capital.

Party	Capital level[b] (dollars)	Acres of rotation					Farm livestock program		Return (dollars)
		$CCSb_1$	$CCSb_3$	$CSbCOM_3$	$CCOM_3$	Disposal land	Calves (no.)	Hogs (litters)	
A (Landlord	2,000	---	146	7	---	---	---	10	4,435
(Tenant	4,000	---	146	7	---	---	---	10	2,398
B (Landlord	500	129	---	---	---	---	---	---	2,854
(Tenant	Unlimiting	---	---	---	153	---	55	10	2,814
C (Landlord	Unlimiting	---	---	153	---	---	44	10	4,818
(Tenant	3,000	---	140	---	---	13	---	---	2,025
D (Landlord	Unlimiting	---	---	153	---	---	44	10	4,818
(Tenant	Unlimiting	---	---	---	153	---	55	10	2,814

[a]Tenant furnishes labor and operating expenses; landlord pays real estate expenses. All other receipts and expenses shared 50-50.

[b]Capital available for use in the farm business.

higher profits to the tenant from engaging in livestock enterprises causes his optimum plan to differ from that of the landlord.

Table 7 summarizes the most profitable programs for the landlord and tenant under a typical livestock-share lease at various vapital levels. Complete agreement between landlord and tenant is reached when the landlord has $2,000 capital and the tenant has $4,000 capital (roughly the same relative capital limitations for each party, A in Table 7). Because operating expenses and real estate expenses are paid individually, the net return and capital requirement for each activity is somewhat different for the two parties. Yet the same activities hold a relative advantage for both parties, thus permitting identical optimum programs. Further, if the capital resources of the two parties are combined (a total of $6,000 = $2,000 + $4,000) the optimum plan for the farm as a whole is exactly the same as that for each party individually (A in Table 7). Also, the return from this optimum farm plan equals the sum of the returns to the individual parties.

When both the landlord and tenant have unlimiting capital, their most profitable programs are somewhat different (D in Table 7). This difference is slight, however, since additional computations (not shown here) reveal that the landlord can shift to the tenant's optimum plan with a decrease of only $14 in over-all net return; the tenant can shift to the landlord's optimum plan with a decrease of less than $50 in net returns. Such small differences can be easily resolved. The variance in optimum plans can again be attributed to the specialized payment of expenses associated with the machinery and real estate resources.

The landlord and tenant interests are nearly parallel under a livestock-share lease when each party has roughly the same relative capital limitations. Table 7 indicates, however, that conflict still exists if the two parties have widely different capital resources (B and C in Table 7). This finding provides further evidence that leasing shares must be allowed to vary with the capital resources of the parties involved if leasing efficiency is to be attained relative to profit maximization by both parties.

Other Ends

While this study is somewhat methodological in nature, it does allow some practical analysis of economic constructs which relate to tenure. It has previously been denoted that certain leasing conditions are necessary for leasing efficiency.[1] However, this study shows that while these conditions may be necessary, they are not sufficient. Differences in capital appear to be as important as leasing constructs in causing tenure arrangements to be conflicting or consistent between tenant and landlord.

Too, other nonprofit ends may be important to the tenant and landlord in specifying farm plans. This study has not considered these more subjective ends, although certain types of subjective goals might be employed as restraints in further studies using the linear programming technique.

[1]Cf. Heady, Earl O., Economics of farm leasing systems. Jour. Farm Econ. 29; Johnson, D.G., Efficiency and share leasing contracts. Jour. Polit. Econ. 58; Ratchford, B.C., Farm tenure in a dynamic economy, North Carolina Agric. Exp. Sta. Bull. 299.

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LINEAR PROGRAMMING WITH VARIABLE RESTRAINTS[1]

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Linear programming methods are becoming increasingly important for analyzing economic situations. In particular, programming methods have been extensively applied to farm management problems where maximum revenue defines optimum solutions. In these problems, the magnitude of attainable revenue depends on the alternatives of resource use and boundaries of the planning situation as represented by available resource supplies. This paper deals with the latter stipulation concerning resource supplies.

These resources or restraints of the planning situation take many forms. They may be represented by total acres of arable land, amount of operating capital, total hours of seasonal labor, managerial limitations for livestock production, and so on. Also, the optimum programming solution is valid for only the specified amounts of these resource supplies as designated at the outset of the programming problems.

Programming Modifications

A more comprehensive method of programming is one that allows variation of resource supplies.[2] That is, a method that determines continuous optimum solutions when one resource supply is varied within a relevant range and other resource supplies are held constant.

One such method developed by Candler[3] is a modified simplex solution for linear programming with variable capital restrictions. In review, Candler's method involves a ratio criterion for selecting activities that give successive capital optima solutions. Although this method illustrates variation of the capital resource, it has parallel application for any other resource or restraint in the programming model. Originally, this continuous capital solution required computation of three possible test ratios for each activity if the original matrix contained any negative input-output coefficients; particular rules were specified for sorting out the critical ratio and corresponding activity to be included in the next iteration. However, a footnote toward the end of Candler's article recognizes that all programming problems (even those with negative coefficients) can be solved with less complexity by computing only one test ratio for each activity. This ratio, d_j, is a positive capital coefficient

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[2]It is assumed that the reader is already acquainted with the simplex method of linear programming that requires fixed restraints or resource supplies.

[3]Candler, Wilfred V. 1956. A modified simplex solution for linear programming with variable capital restrictions. Jour. Farm Econ. 38(4).

divided by the corresponding negative $Z_j - C_j$ entry. If the specified signs do not occur as indicated, a d_j ratio does not exist for the activity concerned. Capital optima solutions are determined by introducing the activity with the most negative d_j ratio at each iteration.

This paper discusses a different modification of the simplex solution with continuous variation of one restraint. We believe the method proposed here has considerable advantages for programming on high speed computers. The procedure is numerically illustrated by use of a sample problem from Candler's article. For the advanced programmer, algebraic logic and computations are explained in an appendix.

Computational Considerations

Empirical applications of the continuous capital solution yields continuous optimum solutions for the capital range designated. Thus, programming results are easily exhibited in graphic form with capital supplies on one axis and total returns on the other. Such an illustration shows the relation between increases in return from increasing amounts of capital.

Because of increasing scope and size of the problems being tackled, programmers are seeking the aid of electronic computers. However, little effort has been extended toward writing variable restraint programs for electronic machines. In fact, it was in this vein that the variable restraint method to be presented here was realized.

Hand versus machine methods. Computation of a "decision row" (d_j row) in Candler's method is a relatively efficient manner for determining capital optima iterations by hand. In addition, a ΔP_0 column is included to record the increments of increased capital required for each iteration. For clerical help using desk calculators, this entire process is quite short and easy to learn. However, for the computational method normally employed on high-speed computers, Candler's procedure is cumbersome. The reasons are somewhat technical: In standard simplex programming on high-speed computers, the original tableau of coefficients is not fully transformed at every iteration. Instead, only the "net price" row ($Z_j - C_j$) and two columns—the P_0 column and the column of coefficients for the currently incoming activity—are computed for the new tableau (see e.g., Orchard Hayes, "Evolution of Computer Codes for Linear Programming." Santa Monica, Calif., Rand Corporation, 1956).

To compute the d_j ratio in Candler's method, extra computation is required. Namely, the capital row (or the row corresponding to the variable resource) must be computed for each iteration in addition to the $Z_j - C_j$ row and the two columns just mentioned. Moreover, this extra computation requires extra storage space in the memory of the machine.

For the modified programming method presented here, no additional row need be computed for the transferred tableau. In fact, the procecure consists of the standard simplex method with a modification in three of the computer instructions. By this means, variable capital problems can be handled with the standard computing program—requiring only a few additional instructions and little extra storage in the memory of the machine.

A Sample Illustration

The "typical or more complicated" example in Candler's paper is used to illustrate the clerical procedure. The problem and iterative steps for determining capital optimum solutions are presented in Table 1.[1] One minor exception to Candler's original problem should be noted. This deviation occurs in the original supply of capital (i.e., the entry for the P_4 row in the P_0 column). This initial supply of capital ($C_0 \geq 0$), with our method, is chosen as the minimum amount of interest in the problem concerned (in this case, we have chosen C_0 = ₿100). Also, choosing an initial amount greater than zero avoids extra computations that give an optimum solution for zero amount of capital.[2] Such a result is of no value and requires extra time to obtain wanted or practical results. Hence, if the original capital supply is assumed as some quantity greater than zero, no violation of the procedure occurs and computing time is reduced.

The basic problem is identified in section 0 of Table 1. The first restraint, capital, in the P_0 column is to be varied from ₿100 (C_0) to an unlimiting amount. There are three production alternatives (P_1, P_2, and P_3) and five restraints (rows P_4 through P_8).

Step 1, or initial calculation, follows the simplex routine. That is, the most negative $Z_j - C_j$ value is the criterion for selecting an incoming activity, and the smallest positive ratio in the R column identifies the outgoing row. This procedure finally results in section 3 (t = 3, see index in last column of Table 1) where all $Z_j - C_j$ values are positive; the optimum plan includes production of .69 units of P_2, 2.759 units of P_1, and .69 units of P_3. Values for P_5 and P_6 represent unused supplies of building space and labor. Total return is ₿86.90 (i.e., the $Z_j - C_j$ entry for the P_0 column). Section 3 is an optimum plan for ₿100 of capital.

Step 2 is to increase capital to the maximum allowable amount (ΔC_1) that retains the same set of optimum activities in the plan. This allowable amount, ΔC_1, is found by computing the ratios:

$$R = P_0 \text{ entry/corresponding entry in the capital slack vector}$$

using negative divisors only. These ratios, R, are shown in the next to the last column of Table 1. The smallest numerical ratio, R_{min}, is the maximum allowable change in capital, ΔC_1. (See derivation in appendix.) In section 3 of Table 1, this smallest ratio is -189.904 which occurs in the second, or P_5, row. Thus, the activities in section 3 remain in the optimum plan as capital use is increased by ₿189.904 above the ₿100 supply assumed at the outset.

[1] To facilitate algebraic explanation and proof of our method, the identity or disposal columns are listed on the right-hand side of the programming tableau.

[2] This outcome or situation does not apply to all problems. But it does exist in the particular example used in this paper and similar problems will present the same condition.

The level of each activity in the optimum plan for ₿289.904 ($C_0 + \Delta C_1$ = ₿100 + ₿189.904 = ₿289.904) is computed next. This is done by subtracting the product of -189.904 times the capital slack vector from the P_0 column in section 4.

Calculation		P_0 Value	Row
.690 - (-189.904 x .007)	=	2.000	P_2
65.517 - (-189.904 x -.345)	=	0	P_5
89.655 - (-189.904 x -.104)	=	70.000	P_6
2.759 - (-189.904 x .028)	=	8.000	P_1
.690 - (-189.904 x .007)	=	2.000	P_3
86.897 - (-189.904 x .869)	=	252.000	Z-C

The resulting P_0 vector pertains to an intermediate iteration, section 3', which is not shown in Table 1. Section 3' has the P_0 value shown above and all other column values as given in section 3 of Table 1. In other words, only the P_0 vector in section 3 is treated to determine section 3'. This latter manipulation strays from the standard simplex method of computations. However, it maintains a feasible solution for ₿289.904 of capital since all values in the P_0 column of section 3' are positive or zero. And the solution is optimum since no $Z_j - C_j$ values are negative. Note at this stage that one activity (in this case, P_5) is in the set at zero level.

Step 3 occurs at this stage of the modified programming routine. We can now alter the set of activities by introducing another activity at zero level and not affect the level of profit or other activities in the plan at this stage. More specifically, the P_0 column for section 3' contains a zero value in the P_5 row which is replaced by the capital slack vector without altering the positive P_0 values of section 3'. However, other columns in section 4 have been transformed according to simplex rules by introduction of the capital slack vector. The result is a negative $Z_j - C_j$ entry under the P_7 column. The only new concept at this point is that a negative pivot (-.345) is used in the incoming column.

It should be noted here that steps 2 and 3 have been spelled out separately to convey the logic of the procedure. Actually, these steps can be combined into one interation as shown in Table 1. This shortcut is explained as follows: "At the end of the ordinary simplex procedure (section 3), bring in the capital slack vector on the line in which the numerically smallest negative R ratio occurs (line P_5). Having completed this transformation into the following section (section 4), replace the P_0 value of the incoming row (-189.904 in the P_4 row) with zero." This process yields section 4 directly from section 3.

Step 4 concerns the procedure to follow at the stage corresponding to section 4. Two things are possible at this phase of programming: (1) If all $Z_j - C_j$ values are $\geq$ zero, the problem is completed. (2) If any negative $Z_j - C_j$ values occur, continue programming with the ordinary simplex procedure. The example in Table 1 requires one iteration to complete this step. The capital line, P_4, is replaced by the P_7 column to form section 5. Since all $Z_j - C_j$ values are now ≥ 0, step 4 is completed. If some $Z_j - C_j$ values were < 0 in section 5, step 4 would be

continued by bringing in other activities on the same line at zero level. The latter condition is explained by the zero R ratio which will always occur on the row corresponding to the position of the capital slack vector at the end of step 3 (section 4 in Table 1).[1] (Also see explanation in appendix.) At this point, revert to steps 2 and 3 above. That is, one continues cycling through steps 1, 2, and 3 until all $Z_j - C_j$ values are ≥ 0 or maximum amount of capital has been reached.

The entire computational procedure can be described by the following rules.

Rule 1. Complete standard simplex computations for the minimum amount of capital, C_0.

Rule 2. Bring in the capital slack vector on the line in which the numerically smallest negative R ratio (P_0/capital slack vector) occurs. Then replace the P_0 value of the incoming row by zero.

Rule 3. Continue standard simplex procedures until all $Z_j - C_j$ values are $\geq$ zero.

Rule 4. Revert to rule 2. The process will continue until one of two situations occur:

A. In rule 2, no negative ratio can be found. In this case, capital is actually the only essential restriction. That is, any further increase in capital will result in proportional increases in profit. Likewise, other activities contained in the P_0 column are proportionately increased according to the proportionality factors or values found in the capital slack vector. An example of this situation occurring is when all resource supplies can be augmented by acquisition of more capital (i.e., purchasing feed, hiring labor, making capital investments for livestock housing, and so on).

B. In rule 3, no negative $Z_j - C_j$ values occur. For this situation, further increases in capital will leave all values, including profit, of the P_0 column unaltered; it will merely increase the level of unused capital.

Situation B corresponds to the case example in Table 1.

Mathematical Justification of the Procedure

1. Notation (for numerical illustration, see Table 1)

Let us denote by $a_{ij}^{(t)}$ the element of the i-th line and the j-th column of the tableau at the t-th iteration, i.e., in the t-th section of Table 1. The iteration count, t, starts at 0 and goes to section t = 6. The columns containing the $a_{ij}^{(t)}$ run from j = 1 to j = 8 and the lines from i = 1 to i = 6 (e.g., $a_{1,2}^{(0)} = 20$, $a_{2,1}^{(1)} = 12.500$, $a_{6,2}^{(2)} = -126.000$). The slack vector for capital occurs in column j = 4, and the corresponding vector in the t-th tableau (t-th section) is denoted by $a_{i4}^{(t)}$.

[1] If it happens that other zero values occur in the P_0 column at this stage, the computing instructions are such that the outgoing row is the one on which capital was originally at zero level.

Table 1. An Example of Variable Restraint Programming

Column No. j =				0	1	2	3
Line No. (i)	Restraints			P_0	Livestock 21 P_1	Rotation A 10 P_2	Rotation B 32 P_3
i = 1	Capital		P_4	100	22	20	37
2	Building Space		P_5	100	10	0	10
3	Labor		P_6	100	1	10	1
4	Corn		P_7	0	4	-10	-6
5	Manure	⟵	P_8	0	-10	0	40
6			Z - C	0	-21	-10	-32
i = 1			P_4	100	31.250	20	0
2			P_5	100	12.500	0	0
3			P_6	100	1.250	10	0
4		⟵	P_7	0	2.500	-10	0
5	32	⟶	P_3	0	-.250	0	1
6			Z - C	0	-29.000	-10	0
i = 1		⟵	P_4	100	0	145.000	0
2			P_5	100	0	50.000	0
3			P_6	100	0	15.000	0
4	21	⟶	P_1	0	1	-4.000	0
5	32		P_3	0	0	-1.000	1
6			Z - C	0	0	-126.000	0
i = 1	10	⟶	P_2	.690	0	1	0
2		⟵	P_5	65.517	0	0	0
3			P_6	89.655	0	0	0
4	21		P_1	2.759	1	0	0
5	32		P_3	.690	0	0	1
6			Z - C	86.897	0	0	0
i = 1	10		P_2	2.000	0	1	0
2	0	⟷	P_4	0	0	0	0
3			P_6	70.000	0	0	0
4	21		P_1	8.000	1	0	0
5	32		P_3	2.000	0	0	1
6			Z - C	252.000	0	0	0
i = 1	10		P_2	2.000	0	1	0
2	0	⟶	P_7	0	0	0	0
3		⟵	P_6	70.000	0	0	0
4	21		P_1	8.000	1	0	0
5	32		P_3	2.000	0	0	1
6			Z - C	252.000	0	0	0
i = 1	10		P_2	9.001	0	1	0
2	0		P_7	70.000	0	0	0
3	0	⟶	P_4	0	0	0	0
4	21		P_1	8.000	1	0	0
5	32		P_3	2.000	0	0	1
6			Z - C	322.000	0	0	0

4	5	6	7	8		
P_4	P_5	P_6	P_7	P_8	R	Section (t)
1	0	0	0	0	2.703	
0	1	0	0	0	10.000	
0	0	1	0	0	100.000	
0	0	0	1	0		t = 0
0	0	0	0	1	0	
0	0	0	0	0		
1	0	0	0	-.925	3.200	
0	1	0	0	-.250	8.000	
0	0	1	0	-.025	80.000	
0	0	0	1	.150	0	t = 1
0	0	0	0	.025		
0	0	0	0	.800		
1	0	0	-12.500	-2.800	.690	
0	1	0	-5.000	-1.000	2.000	
0	0	1	-.500	-.100	6.667	
0	0	0	.400	.060		t = 2
0	0	0	.100	.040		
0	0	0	11.600	2.540		
.007	0	0	-.086	-.019		
-.345	1	0	-.690	-.035	-189.904	
-.104	0	1	.793	.190	-866.000	
.028	0	0	.055	-.017		t = 3
.007	0	0	.014	.021		
.869	0	0	.738	.107		
0	.020	0	-.100	-.020		
1	-2.899	0	1.999	.100	0	
0	-.300	1	1.000	.200	70	
0	.080	0	0	-.020	∞	t = 4
0	.020	0	0	.020	∞	
0	2.520	0	-1.000	.020		
.050	-.125	0	0	-.015		
.500	-1.450	0	1	.050		
-.500	1.150	1	0	.150	-139.899	
0	.080	0	0	-.020		t = 5
0	.020	0	0	.020		
.500	1.070	0	0	.070		
0	-.010	.100	0	0		
0	-.300	1.000	1	.200		
1	-2.299	-1.999	0	-.300		
0	.080	0	0	-.020		t = 6
0	.020	0	0	.020		
0	2.220	1.000	0	.220		

The resource column (P_0) occurs in column j = 0 and is denoted by $b_i^{(t)}$ so that original resource supplies are called $b_i^{(0)}$. In particular, the (lowest) capital resource ($100) in section t = 0 is shown in the first line (i = 1) so that $b_1^{(0)} = 100$.[1] For this capital resource of $b_1^{(0)}$ = $100, the optimum set of activities is reached in section t = 3.

Denote by E the matrix which transforms the columns $a_{ij}^{(0)}$ to $a_{ij}^{(3)}$ for every j. In particular, we note that this transformation applies to the capital slack column $a_{i4}^{(0)}$, which is transformed to $a_{i4}^{(3)}$ by

$$a_{i4}^{(3)} = E\, a_{i4}^{(0)} \tag{1}$$

The same matrix E also transforms the P_0 column from $b_i^{(0)}$ to $b_i^{(3)}$ so that

$$b_i^{(3)} = E\, b_i^{(0)} \tag{2}$$

2. The first increment in capital resource

We now assume that the capital resource in the original tableau is raised by ΔC so that the only change would be in the P_0 column whose element $b_1^{(0)}$ is replaced by $b_1^{(0)} + \Delta C$. We remember now that the capital slack column $a_{i4}^{(0)}$ has a first element of $a_{1,4}^{(0)} = 1$ while the other elements $a_{i4}^{(0)}$ $(i > 1)$ are 0. Thus we may use this slack column to represent the increased capital increment in the P_0 column in the form

$$b_i^{(0)} + \Delta C\, a_{i4}^{(0)} .$$

Starting with this altered P_0 column and going through the <u>same</u> three cycles from tableau t = 0, we number the new tableau we now reach by t = 3'. All columns, $a_{ij}^{(3')}$, are again obtained by the same matrix transformation E, and hence agree with the $a_{ij}^{(3)}$ shown in section 3 of Table 1. However, the new P_0 column $b_i^{(3')}$ is given by

$$b_i^{(3')} = E(b_i^{(0)} + \Delta C\, a_{i4}^{(0)}) = E\, b_i^{(0)} + \Delta C\, E\, a_{i4}^{(0)} = b_i^{(3)} + \Delta C\, a_{i4}^{(3)} \tag{3}$$

In other words, the P_0 column of tableau 3' is obtained by adding ΔC times the column $a_{i4}^{(3)}$ to the old P_0 column $b_i^{(3)}$. The new tableau is a

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[1] The original supply of capital referred to here as $b_1^{(0)}$ is denoted by C_0 in the preceding text. Likewise, increments of additional capital were denoted by ΔC.

"feasible solution" so long as all elements of the new P_0 column are ≥ 0 (i.e., so long as $b_i^{(3)} + \Delta C\, a_{i4}^{(3)} \geq 0$). (4)

Consequently we distinguish two cases:

2.1 All elements of $a_{i4}^{(3)}$ are ≥ 0.

2.2 At least one element of $a_{i4}^{(3)}$ is < 0.

In case 2.1, the new P_0 column $b_i^{(3)} + \Delta C\, a_{i4}^{(3)}$ is always ≥ 0. Hence, we have feasible solutions for any increment in capital resource $\Delta C \geq 0$, and since $a_{6j}^{(3)}$ (usually called $Z_j - C_j$) are all ≥ 0, all these solutions are optimum. Hence, the set of optimum activities remains the same as in tableau t = 3 (i.e., P_2, P_5, P_6, P_1, P_3), but the levels of these optimum activities are given by formula (4), i.e., they increase linearly with ΔC. Likewise, the profit (given by $b_6^{(3)} + \Delta C\, a_{6,4}^{(3)}$) would increase linearly with ΔC. In this case, the problem is therefore completely solved at this stage.

We now turn to case 2.2. In this case, the set of activities in the P_0 column of tableau t = 3 is feasible (and optimum) only so long as all levels of $b_i^{(3)} + \Delta C\, a_{i4}^{(3)}$ are ≥ 0 for all i = 1, 2, ..., 6. Accordingly, we must impose the restriction that

$$\Delta C \leq \min \frac{b_i^{(3)}}{\left| a_{i4}^{(3)} \right|} = \Delta C_1 \qquad (5)$$

where the minimum value is valid for negative divisors ($a_{i4}^{(3)}$) only. In Table 1, section t = 3, this minimum value occurs in the second line (i = 2) where $a_{2\,4}^{(3)} = -.345$ so that

$$\Delta_1 = \frac{65.517}{-.345} = -189.904$$

The optimum set of activities is therefore the same as for the original capital resource $b_1^{(0)}$ so long as the increment ΔC is less than the critical value ΔC_1 defined by (5).

3. The first change in the set of optimum activities

In case 2.2, we reached a situation where the set of activities which was optimum at capital resource $b_1^{(0)}$ was also optimum at capital resource $b_1^{(0)} + \Delta C_1$ with the levels of the activities given by $b_i^{(3)} + \Delta C_1\, a_{i4}^{(3)}$. There is a particular line (i=2) for which the minimum in (5) is reached and

in this line the new level of the activity (P_5) is 0 (i.e., $b_2^{(3')} = 0$) as shown for the second P_0 value of tableau t = 3' given on page 164.

We now bring in other activities at zero level (in place of P_5). The first of these is the capital column which is "brought in" on the negative element for line i = 2 (-.345 in section t = 3, Table 1). This transformation results in tableau t = 4 whose elements $a_{ij}^{(4)}$ are given by

$$
\begin{aligned}
a_{ij}^{(4)} &= a_{ij}^{(3)} - \frac{a_{i4}^{(3)}\, a_{2j}^{(3)}}{a_{2,4}^{(3)}} \qquad (i \neq 2) \\
a_{2j}^{(4)} &= \frac{a_{2j}^{(3)}}{a_{2,4}^{(3)}}
\end{aligned}
\tag{6}
$$

and whose P_0 column agrees with $b_i^{(3')}$ since $b_2^{(3')} = 0$. In particular, the profit $b_6^{(3')} = b_6^{(4)}$ does not increase by this operation.

Next we bring in other activities at zero level but always on the line i = 2 given by (5). This operation follows standard simplex routine except that any negative a_{6j} (called $Z_j - C_j$) may be used to determine the incoming activity column—not necessarily the most negative $Z_j - C_j$. Thus, we see in tableau t = 4 that a negative $b_{6j}^{(4)}$ occurs for j = 7 (namely, $a_{6,7}^{(4)} = -1.000$), and that elements of the next tableau are therefore given by

$$
\begin{aligned}
a_{ij}^{(5)} &= a_{ij}^{(4)} - \frac{a_{i7}^{(4)}\, a_{2j}^{(4)}}{a_{2,7}^{(4)}} \qquad (i \neq 2) \\
a_{2j}^{(5)} &= \frac{a_{2j}^{(4)}}{a_{2,7}^{(4)}}
\end{aligned}
\tag{7}
$$

Substituting (6) in (7) we can express the elements of the tableau t = 5 in terms of those for tableau t = 3 by

$$
\begin{aligned}
a_{ij}^{(5)} &= a_{ij}^{(3)} - \frac{a_{i7}^{(3)}\, a_{2j}^{(3)}}{a_{2,7}^{(3)}} \qquad \text{for } i \neq 2 \\
a_{2j}^{(5)} &= \frac{a_{2,7}^{(3)}}{a_{2,7}^{(3)}}
\end{aligned}
\tag{8}
$$

Consider now the last line (i = 6) of tableau t = 4 as given by (6), i.e.,

$$a_{6j}^{(4)} = a_{6j}^{(3)} - \frac{a_{6,4}^{(3)}\, a_{2j}^{(3)}}{a_{2,4}^{(3)}} \tag{9}$$

For j = 7 we have a negative price coefficient

$$a_{6,7}^{(4)} = a_{6,7}^{(3)} - \frac{a_{6,4}^{(3)}\, a_{2,7}^{(3)}}{a_{2,4}^{(3)}} \tag{10}$$

which in the example is $a_{6,7}^{(4)} = -1.000$. On the other hand, since all price coefficients $a_{6j}^{(3)}$ In tableau t = 3 are all ≥ 0, it follows from equation (10) that the ratio $a_{2,7}^{(3)}/a_{2,4}^{(3)}$ must be positive (for $a_{6,7}^{(4)}$ to be negative); and since $a_{2,4}^{(3)} < 0$, it follows that also $a_{2,7}^{(3)} < 0$. (In the example of Table 1, $a_{2,4}^{(3)} = -.345$ and $a_{2,7}^{(3)} = -.690$.) Moreover, it follows from equation (10) that

$$0 \geq a_{6,7}^{(4)} = a_{2,7}^{(3)} \left(\frac{a_{6,7}^{(3)}}{a_{2,7}^{(3)}} - \frac{a_{6,4}^{(3)}}{a_{2,4}^{(3)}} \right) \tag{11}$$

and since $a_{2,7}^{(3)} < 0$ that

$$0 \leq \frac{a_{6,7}^{(3)}}{a_{2,7}^{(3)}} - \frac{a_{6,4}^{(3)}}{a_{2,4}^{(3)}} \tag{12}$$

Since both ratios in (12) are negative, this inequality states that the ratio $a_{6,7}^{(3)}/a_{2,7}^{(3)}$ is numerically smaller (but algebraically larger) than the ratio $a_{6,4}^{(3)}/a_{2,4}^{(3)}$ (.738/(-.690) is numerically smaller than .869/(-.345)).

The same argument as the above would apply to the subsequent tableau t = 5 given by (8) if for some column j (say) a negative price coefficient $a_{6j}^{(5)}$ could be found in this column. (Actually in tableau t = 5 they are all positive.) This argument shows that as long as a negative "price" $a_{6j}^{(t)}$ can be found (for the column j to come in), the ratio $a_{6j}^{(3)}/a_{2j}^{(3)}$

will be a smaller negative ratio than the corresponding ratio in the preceding tableau. Consequently, this stage of the operation will bring in new activities on line i = 2 until the activity j with the smallest negative ratio $a_{6j}^{(3)}/a_{2j}^{(3)}$ is reached. (In Table 1, this occurs in tableau t = 4 when the activity j = 7 is coming in for which the ratio $a_{6,7}^{(3)}/a_{2,7}^{(3)} = .690/.738$ is the smallest negative ratio in question.) The maximum number of cycles which may be required to complete this state is therefore equal to the number of negative elements in the line i = 2 of tableau t = 3. Actually there will usually be fewer cycles. Of course, if we decided to program the machine to find the smallest negative ratio $a_{6j}^{(3)}/a_{2j}^{(3)}$ right away and bring in that activity for which this ratio is the smallest negative, we could do this in one cycle. However, as pointed out before, this would require considerable additions in computer storage space which will make this method prohibitive in most computational situations. With the present method, the machine will normally take somewhat longer but is bound to bring in the activity for which $a_{6j}^{(3)}/a_{2j}^{(3)}$ is the smallest negative ratio by standard simplex procedure. After this activity has been brought in, the prices must all be positive because a further negative price in a column j implies a smaller negative ratio $a_{6j}^{(3)}/a_{2j}^{(3)}$ which is impossible.

4. The completion of the operation

We have now reached tableau t = 5 in which all prices are positive. This situation is, therefore, completely analogous to tableau t = 3, and we repeat the same steps of operations starting from tableau t = 5 in place of tableau t = 3. We, therefore, distinguish two cases:

4.1 All elements of $a_{i4}^{(5)}$ are ≥ 0.

4.2 At least one element of $a_{i4}^{(3)}$ is < 0.

In the example, one element, viz., $a_{3,4}^{(4)} = -.500 < 0$; accordingly, we are in situation 4.2 and capital is therefore brought in on the line i = 3 (which now plays the role of the previous line i = 2).

This operation yields tableau t = 6 where we find no negative prices. Hence, we have reached the final tableau with capital in the system at zero level. Any further increases of capital will leave the optimum system completely unaltered except for increasing the level of unused capital. Hence, capital ceases to be an essential restriction at this stage.

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RELATION OF SOLAR RADIATION MEASUREMENTS AT AMES TO SUNSHINE OBSERVATIONS AT DES MOINES[1]

Angelito Sandoval and Robert H. Shaw[2]

The standard instrument for measuring the intensity of solar radiation (insolation) in the United States is the Eppley pyrheliometer. However, these measurements are largely lacking for Iowa. Data have been recorded at Ames only since 1953. During the period of record there are some missing data due to failure of the recorder system. These missing data need to be estimated. In certain studies it would be desirable to have data for years prior to 1953, even if estimated. On the other hand, sunshine data have been recorded at Des Moines for many years. Investigations have shown these observations can be used to estimate intensity data.

In the present study the relationship between the per cent of possible sunshine hours at Des Moines, and solar radiation intensity as recorded by the Eppley pyrheliometer has been evaluated.

REVIEW OF LITERATURE

Despite the importance of insolation in many fields of study, solar radiation data are scarce compared with other meteorological elements being recorded throughout the world. Various formulae have been developed for estimating insolation from meteorological elements such as diurnal temperature, cloudiness, and cloud density. Areal interpolation among radiation stations has also been used. Hamon et al. (5) have pointed out that the use of per cent of possible hours of sunshine is a better indicator of actual insolation than any of these elements.

The use of the per cent of possible hours of sunshine in estimating the amount of insolation was first introduced by Angstrom (1). His formula is expressed as follows:

$$Q_s/Q_o = a + b\,S \tag{1}$$

where Q_s is the total radiation-income during the day; Q_o is the radiation-income which corresponds to a perfectly clear day; S is the duration of sunshine expressed as a percentage of the possible duration; and a and b are constants. Later studies made by various investigators (2, 6, 9) at different places, yielded different values for the constants of Angstrom's formula. Kimball (6) concluded that the difference in the value of the

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constants was in the term that represented the percentage of clear-sky radiation that penetrated a continuous cloud cover.

Decker (3) described a regression equation relating the per cent of possible hours of sunshine, S, to solar radiation, R, as

$$R = a + b\,S \tag{2}$$

where a and b are suitable constants for a given period. His study was conducted at Columbia, Missouri. He developed two listings of regression equations. One set of 12 regression equations was for estimating daily radiation from per cent of possible sunshine with a single equation for each month of the year. A second listing of equations was by intervals of 1/3 of a month throughout the year. All correlation coefficients were significant at the 1 per cent level.

Earlier, Vries (9) in Wageningen, Netherlands had studied the correlation between radiation intensity, I, and sunshine percentage, R, for each month of the year using the linear and quadratic equations:

$$I = a + b\,R \tag{3}$$

$$I = p + q\,R + R^2 \tag{4}$$

where a, b, p, q, and r were constants as determined by the method of least squares. Ressinck, as cited by Vries (9) had noted previously a slight systematic deviation from the linear relation, the curve representing the statistical relation between I and R being concaved towards the R-axis. Ressinck stated that this was probably so because low values of R were usually associated with heavy clouds, while at values of R around 0.5, reflection from the sides of clouds caused an increase in radiation intensity. Although the amount of curvilinearity appeared to be small, a quadratic regression was used in the present study.

METHOD

The solar radiation data used in the study were recorded with a 10 junction Eppley pyrheliometer located on top of the three story Agronomy Building at Iowa State College. The Eppley pyrheliometer is a specialized thermopile. The receiving surface of the inner ring is black (lampblack), and the outer ring is white (magnesium oxide) (Fig. 1). The receiving element is hermetically sealed in a lamp bulb of soda lime glass. The two rings develop different temperatures because of different absorption of solar radiation. The difference in temperature results in an electro motive force (millivolts) which is very nearly proportional to the solar radiation. This can be recorded as millivolts and then converted to radiation intensity, or, by use of a special recorder, a continuous record of the radiation intensity in gram calories per square centimeter can be obtained.

The per cent of possible hours of sunshine was recorded at the Des Moines Weather Bureau Airport Station using a Marvin sunshine recorder up to August, 1954, and the differential between two photo electric

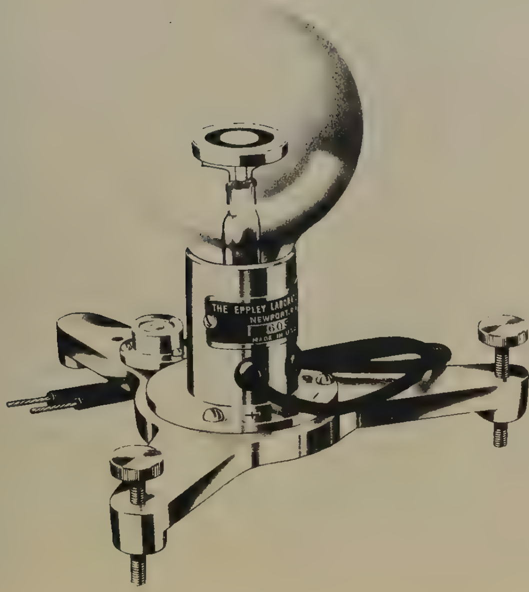

Figure 1. THE EPPLEY PYRHELIOMETER

cells after August, 1954. These instruments record only whether the sun is shining above or below a certain intensity. Any value above this minimum intensity is counted as sunshine, any value below the minimum intensity is counted as no sunshine. These data are published in the Local Climatological Data (7).

Data for the period 1954-57 were used in developing the method of estimating insolation. Because of the proximity of Ames and Des Moines it was felt that the amount of cloudiness would not vary significantly between the two stations, although as will be pointed out later, on a few individual days there may be considerable difference.

The days of the year were divided arbitrarily into ten-day periods as, January 1-10, January 11-20, January 21-30, January 31-February 9, etc. Then the relation between insolation and the per cent of possible hours of sunshine was investigated by plotting scatter diagrams for the individual days of each period. The following curvilinear regression was fitted mathematically:

$$R = a + b S + c S^2 \tag{5}$$

where R is the amount of insolation for a day, S is the per cent of possible

hours of sunshine, and a, b, and c are suitable constants for each period determined by using the method of least squares. Figs. 2, 3, and 4 show representative curves.

For each 10-day period the amount of insolation was computed for 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 per cent of possible hours of sunshine using equation 5. For example for 100 per cent of possible hours of sunshine, S equals 100, for 10 per cent of possible hours of sunshine, S equals 10. The values of a, b, and c were previously obtained for each period when the curvilinear regressions were computed. The value of R obtained by solving the equation was assigned to the fifth day of each period, For the period of January 1-10, the day was January 5 and so on. This gave a series of points for each of the above amounts of possible hours of sunshine for all of the 10-day periods during the year. Because of the short period of record, there was considerable variability between adjacent points. For each amount of sunshine the data were smoothed using a moving average as follows:

$$x_i = \frac{x_{i-1} + 2x_i + x_{i+1}}{4} \tag{6}$$

For sunshine amounts greater than 50 per cent, a smooth curve followed the data points very closely. For lower amounts of sunshine a curve drawn through the data points exhibited considerable waviness. It was not known whether these peaks and depressions were real singularities in radiation or only due to random fluctuation. Since the period of record was short, it was decided to draw a smooth curve through the data points for each level of sunshine.

RESULTS AND DISCUSSION

Figs. 5, 6, and 7 show the final graphs for the conversion of per cent of possible hours of sunshine at the Des Moines Weather Bureau Airport to the amount of daily insolation at Ames. To test the validity of the final chart, values of solar radiation were estimated from the graph for periods not included in the development of the original equations and were compared with the solar radiation actually measured in those periods.

Ten days for each month from October through December, 1953 and from January through May, 1958 were randomly selected. In the case where the observation for a selected day was missing, the day preceding or following was used, whichever was available. A total of eighty days was selected.

The scatter diagram showing the relationship between the observed and estimated solar radiation at Ames is presented in Fig. 8. As expected, there were some days when cloudiness between Ames and Des Moines did not coincide. These days are clearly seen in the diagram. They deviate significantly from both the computed and 45° lines. Three days out of eighty randomly selected were found to deviate markedly.

In the analysis of the data, the correlation between the values of solar radiation observed and estimated was tested. It was found that the correlation was 0.94 and the standard deviation was 52.3 gm-cal cm^{-2} day^{-1}.

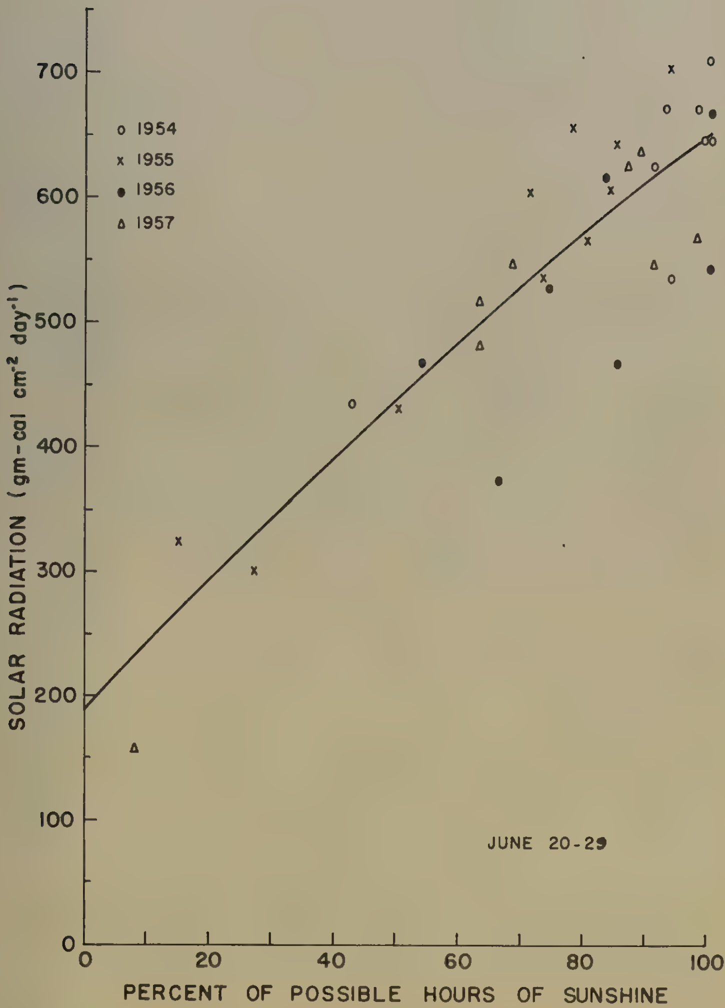

Figure 2. Scatter diagram showing observed daily solar radiation at Ames as a function of observed daily per cent of possible duration of sunshine at Des Moines, daily values, for June 20-29.

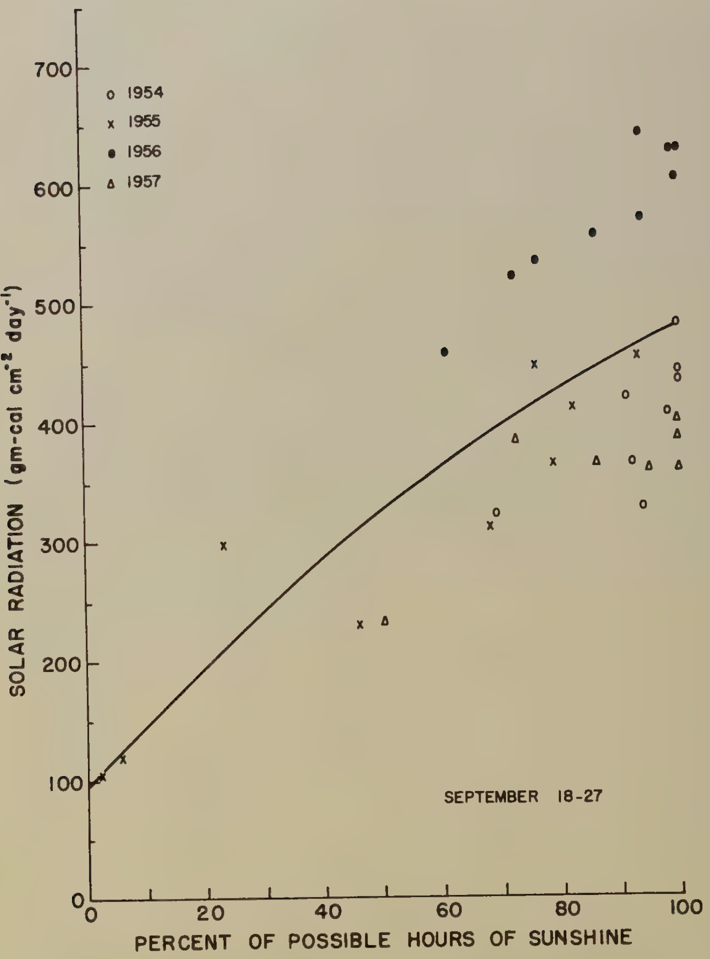

Figure 3. Scatter diagram showing observed daily solar radiation at Ames as a function of observed daily per cent of possible duration of sunshine at Des Moines for September 18-28.

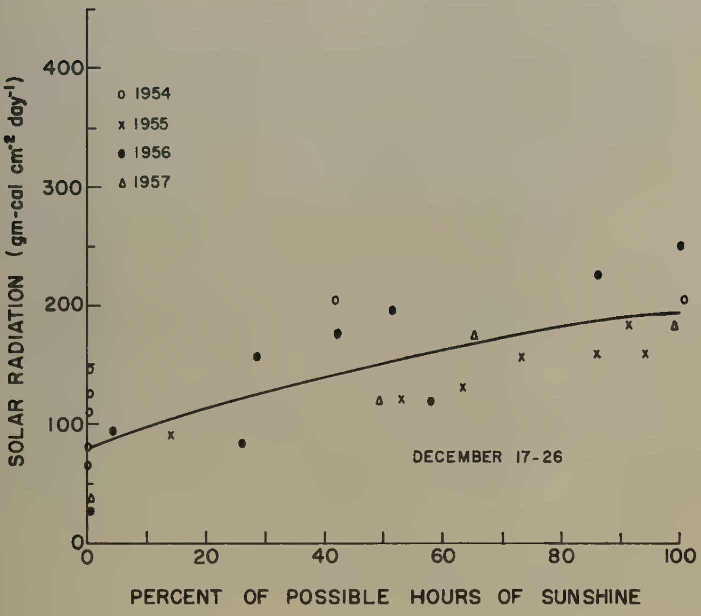

Figure 4. Scatter diagram showing observed daily solar radiation at Ames as a function of observed daily per cent of possible duration of sunshine at Des Moines for December 17-26.

This compared favorably with the results of Decker (3) based on the period of record from 1945 through 1951.

The test showed that there was a very good agreement between the per cent of possible hours of sunshine and solar radiation for the period tested in this study. It appears possible then that solar radiation can be estimated with a reasonable accuracy by this method. It is felt that the relationships found can provide a means of estimating solar radiation at Ames for those days when observations are missing in order to have a complete record. It should also be a useful tool for estimating solar radiation at this station for the years prior to 1953 before pyrheliometer observations were taken.

The error of the estimate of solar radiation due to residual scatter may be attributed to the following: (a) variability in the character of clouds and other restricting phenomena and the time of occurrence (Hamon et al., 5); (b) the difference in the amount and thickness of the cloud between Ames and Des Moines; and (c) noncoincidence of cloudiness between Ames and Des Moines on some days of the year.

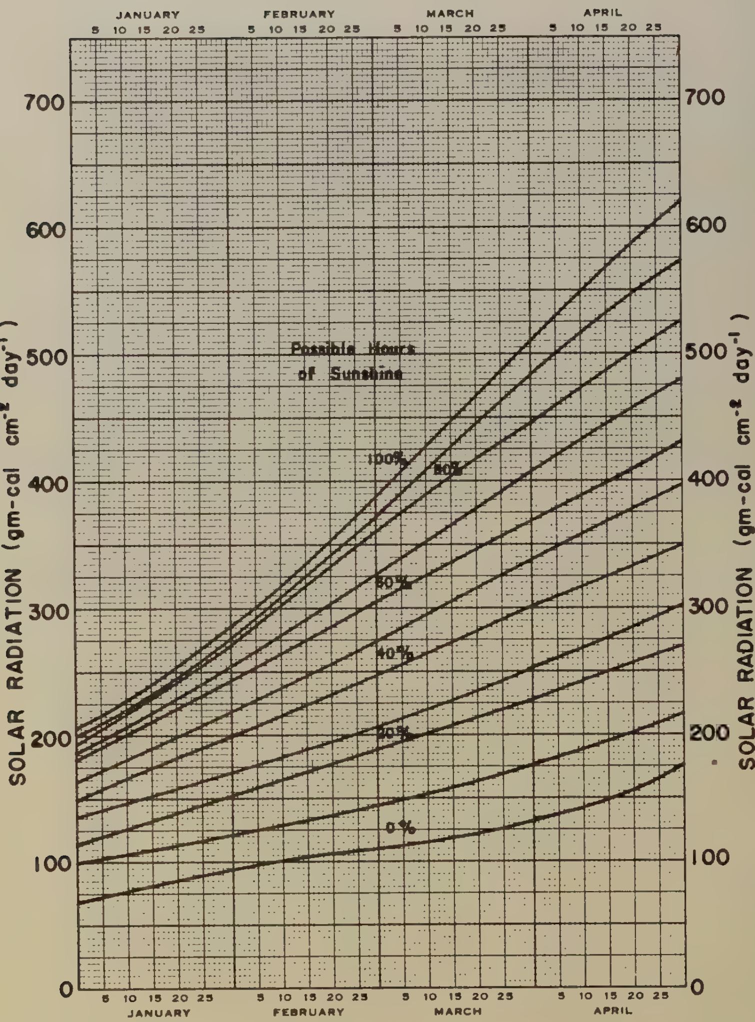

Figure 5. Chart for computing solar radiation at Ames as a function of per cent of possible hours of sunshine at Des Moines from January through April.

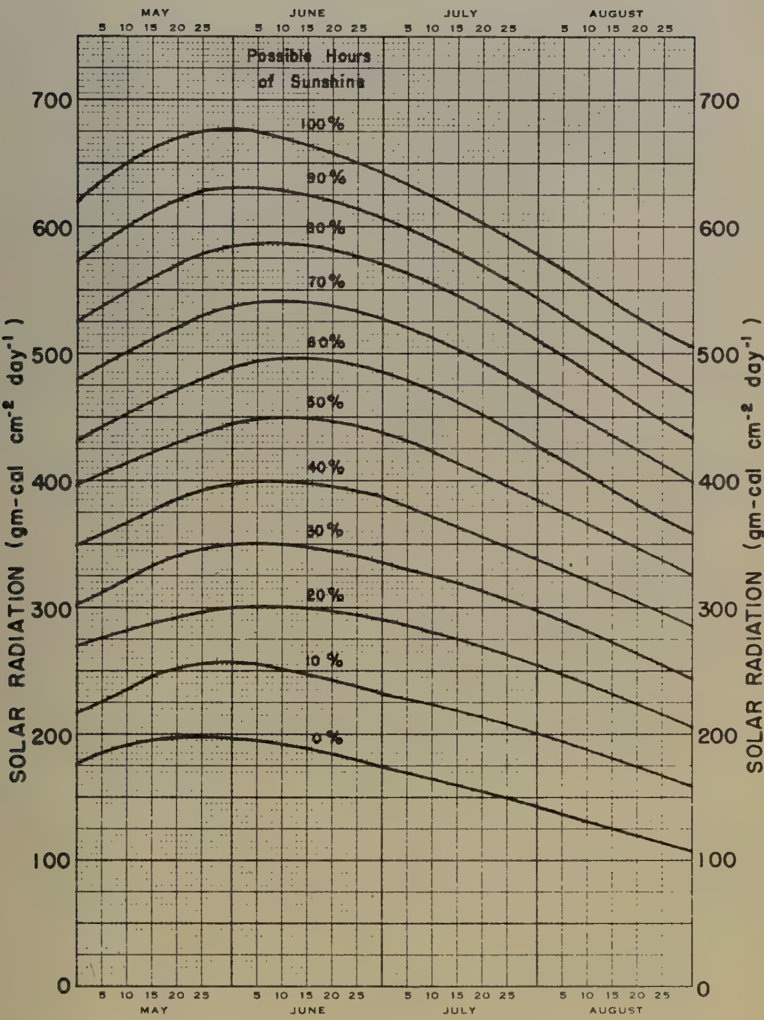

Figure 6. Working diagram for computing solar radiation at Ames as a function of per cent of possible hours of sunshine at Des Moines and time of year from May through August.

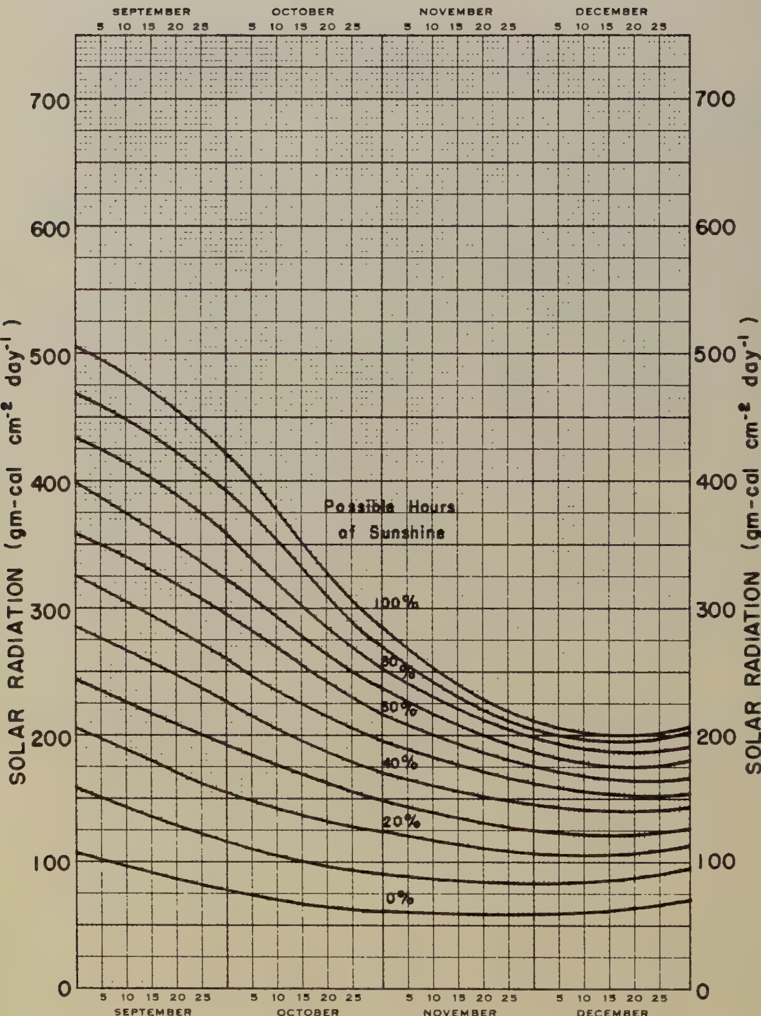

Figure 7. Chart for computing solar radiation at Ames as a function of per cent of possible hours of sunshine at Des Moines from September through December.

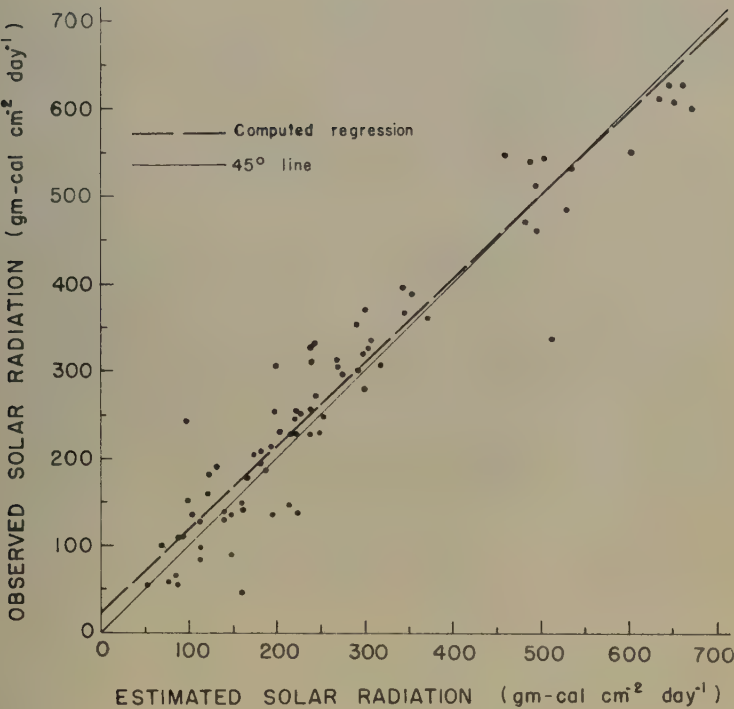

Figure 8. Relation of estimated and observed solar radiation at Ames.

SUMMARY

The relations between the observed daily solar radiation at Ames and (1) the observed possible hours of sunshine and (2) time of the year were developed. These relations were combined into a working chart for converting the per cent of possible hours of sunshine at Des Moines into daily values of solar radiation at Ames. A correlation coefficient of 0.94 between the estimated and observed values of solar radiation was obtained for a sample of eighty randomly selected days.

LITERATURE CITED

1. Angstrom, A. 1924 Solar and terrestrial radiation. Roy. Meteor. Soc. Quart. Jour. 50:121-125.
2. Black, J.N., C.W. Boynthon and J.A. Prescott. 1954. Solar radiation and the duration of sunshine. Roy. Meteor. Soc. Quart. Jour. 80:231-233.

3. Decker, W. L., Columbia Missouri. 1958. Information on regression equations and correlation coefficients which relate the per cent of possible sunshine with solar radiation at Columbia, Missouri. (Private communication.)
4. Fritz, S. and T.H. MacDonald. 1949. Average solar radiation in the United States. Heating and Ventilating. 46:61-64.
5. Hamon, R.W., L. L. Weiss, and W. T. Wilson. 1954. Insolation as an empirical function of daily sunshine duration. Monthly Weather Rev. 82:141-146.
6. Kimball, H.H. 1927. Measurements of solar radiation intensity and determinations of its depletion by the atmosphere with bibliography of pyrheliometric measurements. Monthly Weather Rev. 55:155-169.
7. U.S. Weather Bureau. Local climatological data. Des Moines, Iowa. October 1958 through May 1958.
8. _____. 1952. Manual of radiation observations. Cir. N. 6th ed. Washington, D.C.
9. de Vries, D.A. 1955. Solar radiation at Wageningen. Mededelingen van de Landbouwhogeschool. 55:277-304.

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CLIMATIC RACES IN GUATEMALAN MAIZE[1]

John M. Green[2]

The existence of climatic races in natural populations has been demonstrated in many studies. The existence of ecotypes within a species and of variability within the ecotypes provide good evidence that the species is dynamic (Clausen, Keck, and Hiesey, 1948). In natural populations of this type evolutionary processes are operative; in cultivated crops a parallel situation exists but man attempts to direct the changes which take place. The existence of climatic races in cultivated crops has been well demonstrated, especially in regional and national variety testing programs. The development of specialized ecotypes is of considerable economic importance to the cultivator, and the amount of variability permissible within the ecotype is often determined by economic consideration. An example is provided by machine harvested crops, which require uniformity in height, maturity, etc., to adapt them to mechanized production practices.

In an area where a cultivated crop is handled in a primitive manner by primitive people, the methods employed in the study of natural populations can be utilized to determine the degree of specialization within the crop.

Corn is well established as a major food crop of Guatemala; it is perhaps the major food crop for the great majority of the population. In most instances it is grown as a subsistence crop. Corn growing belongs primarily to the Indians. In the medium altitudes where coffee is the major cash crop, each coffee finca has a sizeable population of Indian laborers. Each Indian family usually has an area of land on which to grow corn, the land being cleared on otherwise uncultivated mountain slopes. In other areas and in villages where the Indians live independently of large plantations, corn may be grown partly as a cash crop, but it is still an individual family enterprise.

Inherent in the system of production in Guatemala is a pressure for development of locally adapted biotypes. Each family saves seed from its own crop for replanting, since there is little assurance that cash will be available for purchasing new planting seed. The development of locally adapted types also is accentuated by extreme difference in altitude in a small area. Field corn collections to be discussed here came from elevations ranging from less than 100 to over 8,300 feet.

Anderson (1947) has discussed the difficulties involved in collecting popcorn and brewing types in Guatemala. His thesis that there is more variability present than is observed by collectors is accepted by the

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writer. It is not the purpose of this report to describe the total variability in corn in Guatemala; its purpose is to elucidate the question of the existence of ecotypes within the range of collections of field corn grown by the Iowa State College-Guatemala Tropical Research Center in 1946.

MATERIALS AND METHODS

The field trial data in this study were taken in 1946 by the Iowa State College-Guatemala Tropical Research Center headed by Dr. Irving E. Melhus. Complete data are filed in the library of the Servicio Cooperative Interamericana de Agricultura in Guatemala.

In 1944 and again in 1946 samples of field corn were collected from many areas of Guatemala. All available sources of harvested corn were utilized, includ' ' the growers' storage places, the market, and other individuals and agencies involved in making collections. Usually the sample consisted of a few pounds of shelled grain (or the equivalent in ear corn), and available information on the area where the corn had been grown was recorded.

In 1946, 175 individual collections were grown, including some collections imported from Mexico, Cuba, Venezuela, and Central American countries other than Guatemala. All of these imports were excluded from the present study, along with Guatemala collections on which exact information concerning the altitude of the source was not available. The remaining 103 collections, data on which are summarized here, are briefly described in Appendix Table II.

Replicated tests including varying numbers of collections were grown at 5 locations. Complete data were obtained in tests grown at elevations of about 75, 5000, and 8100 feet. Data presented here include plant height with tassels exserted, yield of air-dried ear corn in bushels per acre, and susceptibility to corn rust (Puccinia sorghi Schw.) at the 8100 feet elevation. Maturity was scored 0 to 5, with 0 ready for harvest and 5 latest within each test, and rust scores were 0 to 4, with 0 most resistant.

Test locations

The test location at the lowest elevation was on the Alotenango Finca of the United Fruit Co., near Tiquisate, the headquarters town for their Pacific coastal plain plantations.

The tests were planted at elevations very close to 5000 feet. The most extensive planting was at the National School of Agriculture, known also as Finca Barcena. The response of the crop was considered better at Barcena than at the 5000 feet location which served as headquarters for the Iowa State College-Guatemala Tropical Research Center on the outskirts of Antigua, where the fields were small, with large avocado trees in the fence rows, and the test plots suffered from tree competition and damage to ears by parakeets. Data have been used from Barcena, except for plant height which was taken only at Antigua, to represent the 5000 feet elevation.

The high altitude location was on an experiment station operated by the Ministry of Agriculture, near Quezaltenango. The test field was at an altitude of 8133 feet.

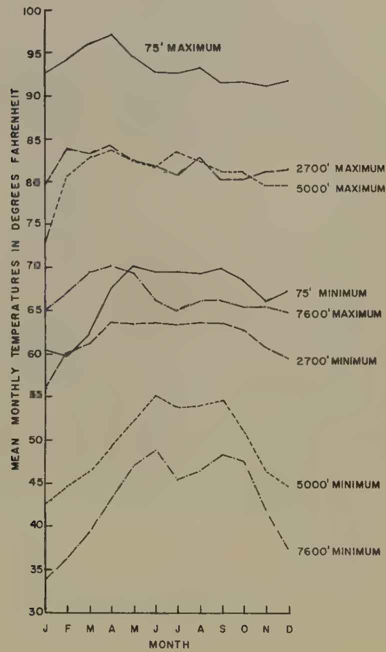

Fig. 1. Mean monthly maximum and minimum temperature at four elevations in Guatemala.

Climatic factors

Climatological data are presented for four elevations on the Pacific slope. Average maximum and minimum temperatures and rainfall data are from near the test locations at 75 and 8133 feet elevations. At 2700 feet elevation the data are from Finca Chocola, one of the test locations from which complete data were not obtained. Weather data for 5000 feet elevation are from Finca Retana near the test at Antigua. Average annual rainfall totals in inches and the number of years in the average were as follows: At 75 ft., 35.8 (5 yr. avg.); at 2700 ft., 161.7 (5 yr. avg.); at 5000 ft., 35.8 (13 yr. avg.); and at 8133 ft., approximately 37 inches. Data for the test at 8133 ft., were obtained from the Ministry of Agriculture in 1957 as an average, but the number of years was not indicated. Temperature data are for the same periods of years as indicated above except at 2700 ft. These data were obtained from the Ministry of Agriculture. Data presented graphically in Figs. 1 and 2 show pertinent climatic conditions under which the collections of corn were developed.

Rainfall appears to be the determining factor in time of planting, although the growing season also coincides with the period of least diurnal

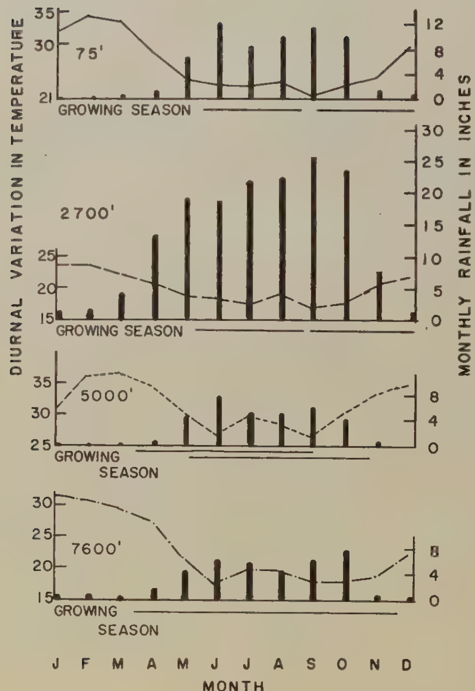

Fig. 2. Mean monthly rainfall totals and diurnal variations in temperature at four elevations in Guatemala. Average growing seasons for maize are indicated by bars at the base of each graph.

variation (Fig. 2). Two successive crops per season are grown at altitudes up to approximately 3000 feet, with plantings usually made in May and September. At 5000 feet, some growers plant in March, while others prefer May, but only one crop is grown. At 8000 feet, planting is usually done about March 15. Time required from planting to harvest varies from approximately three months at the lowest altitude to seven to eight months at 8000 feet.

EXPERIMENTAL RESULTS

Average yield responses of collections grown at approximately 75, 5000, and 8133 feet elevations are shown in Fig. 3. Included in these averages are only those collections grown at all three locations. Because the tests planted were not originally designed for the study of climatic races, only a few collections from each altitude were included in all tests, with the major emphasis at a given elevation on testing

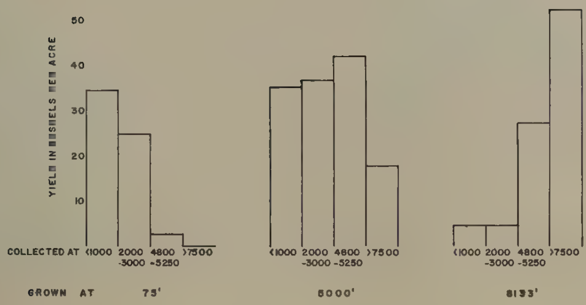

Fig. 3. Average yield responses of collections of maize from the indicated altitudes when grown in common environments at three elevations. (Only 3 collections from below 1000' are included in the average at 8133'; all other averages are based on the numbers indicated in the text.)

locally collected types and less emphasis testing those from other parts of the country. Data presented in Fig. 3 are based on 6 entries collected from below 1000 feet, 8 from 2000-3000, 9 from 4800-5250, and 3 from over 7500 feet. Data on all entries at each location are presented in Appendix Tables I to IX.

The data in Fig. 3 clearly show the existence of adaptive specialization, with the climatic races from collections at over 7500 feet producing very little grain when grown at the lowest elevation. Two of the three collections included in this average tasseled but failed to silk. In the test at 5000 feet elevation, all collections produced some grain, with the locally collected types producing the most. At 8133 feet, the yield responses were almost a mirror image of the responses at the lowest elevation.

Maturity scores are shown in Fig. 4. These scores are comparable only within locations, since each test was scored at the beginning of the harvest, with those collections ready for harvest scored 0 and the latest in the test scored 5. It appears that the practice of growing two crops per season has led to the development of early types in the collections from 2000 to 3000 feet. The types collected from below 1000 feet when grown at the lowest altitude test produced mature grain in a slightly shorter period than did those from the 2000 to 3000 feet area. When compared within tests, however, types from below 1000 feet appeared to be slightly later genetically than the collections from the 2000 to 3000 feet area. Collections from around 5000 feet were late at all locations, and the practice of growing only one crop at that elevation may have led to the isolation of full season types. The collections from above 7500 feet were scored latest in the low altitude test because of the failure of two entries to silk, but data from the other locations indicate that these might be genetically earlier than the types collected from 5000 feet.

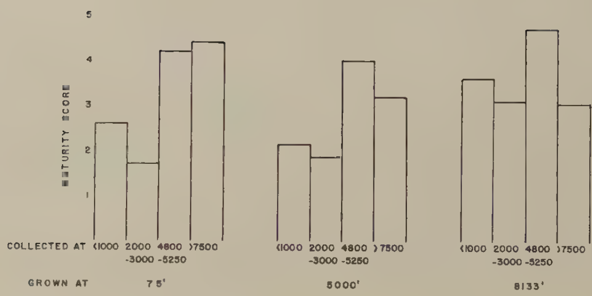

Fig. 4. Average maturity scores of collections of maize from the indicated altitudes when grown in common environments at three elevations.

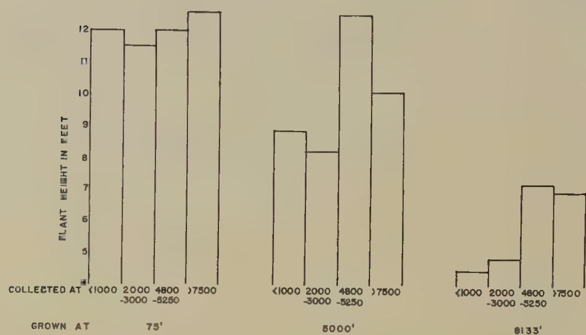

Fig. 5. Mean plant heights of collections of maize from the indicated altitudes when grown in common environments at three elevations.

Plant height (Fig. 5) was not a good character for detecting climatic races, although there was a differential response between the tests at the 75 foot and the other two locations. The trend for all types to be shorter when grown at increasing altitudes was more marked than any differential response of climatic types. The extreme shortening of the types collected from the lower altitudes when grown at the highest elevation could be interpreted as an indication of specialization, but the response of this character is more useful in corroborating results obtained with yield than it is as a single criterion.

DISCUSSION

It seems clear from the data presented that the corn grown at various elevations in Guatemala is best adapted to the elevation where it originated. The data presented were taken in a single year, and are less reliable than average results would be, but the clear-cut nature of the differences observed make it appear unlikely that the results could not be repeated consistently. The production of grain by all types tested at the intermediate elevation indicates that although specialization of climatic races has taken place, there is no barrier to hybridization of the types other than spatial isolation.

The question of transport of the varieties from one part of the country to another by the people can be answered in part by study of the array of types within an altitude group in the appendix tables. Only two of the collections from near 5000 feet produced yields of over 20 bushels per acre when tested at the lowest elevation (Appendix Table I). One of the collections from this same area produced an unusually high yield at 8133 feet (Appendix Table III), but none of the other collections was sufficiently divergent from its respective group's performance to be suspect. Further evidence of the lack of mobility of varieties is given in Appendix Table X, which shows the reaction to leaf rust of all collections grown at 8133 feet. All collections from 2400 feet and below are susceptible; 2800 to 2900 feet appeared to be a transition zone, and from 4130 feet and above only one collection was susceptible. This proved to be one of the two that yielded more than expected at the 75 foot elevation test.

At the time this study was made, there existed specialized types that can be called climatic races. The extent of variability within the isolates might not have been great enough to satisfy Clausen, Keck, and Heisey's (1948) definition of a dynamic species. The data in Appendix Table XI indicate considerable uniformity in kernel color within collections. Anderson (1947) studied ear and kernel characters in Guatemalan corn, and stated that the "varieties" studied were strikingly more uniform than any corn belt varieties he had observed. Two characters observed by the author to be strikingly uniform throughout all types were shank length and ear number. Almost all collections had a short shank, resulting in upright ears, and all were predominantly single eared. The highest average ear number of any collection studied in 1946 was 1.3, and the second ears were definitely nubbins. (Some imported strains included in the tests were definitely prolific types.)

Mangelsdorf and Cameron (1942) postulated that corn had been introduced to the highlands of Guatemala from South America, and that the types found at lower elevations were a product of the original highland type (which was still present) crossed with a species of Tripsacum, this cross also having given rise to Euchlaena. Although results from this study provide no critical evidence on this point, the specific adaptation of the types from 7500 feet and above to the highest test location could be interpreted as evidence that this type was ancestral to the other types which were somewhat more tolerant to extreme differences in elevation. On the other hand, in absence of data other than those presented here, it could be argued that the types from the intermediate elevations had

been introduced, and that selection had provided adaptation to the extreme elevations. Whatever may have been the course of development of races of Guatemalan maize, there existed at the time of this study distinct climatic races, within which there were divergent types so far as ear size and shape, kernel color, texture, and shape, plant pigmentation, etc. are concerned. The high degree of uniformity within "varieties" suggests that there has been consistent selection for type. Such selection, whether to satisfy individual whims, end use needs (brewing, food, stalks for fence building, etc.), or special needs for religious uses, has resulted in a wide array of phenotypes. To elucidate the origin of the many types present, a more comprehensive study such as that done in Mexico (Wellhausen, et al., 1952) would be needed.

SUMMARY

1. Corn collected at elevations varying from 250 to 8300 feet in Guatemala were grown in test plantings at approximately 75, 5000, and 8133 feet elevation in 1946.

2. Yield responses of the collections grown indicated a marked specialization of types; this specialization was considered to establish the existence of climatic races.

3. Yield was the best criterion for distinguishing races; results with maturity and plant height were less definite.

4. Evidence of transport of types from one area to another was rare; 2 of 103 collections appeared not to fit the altitude where they were collected.

5. Most collections were strikingly uniform, indicating effective selection for type as well as for adaptation over a period of time.

6. The data indicate the operation of evolutionary processes within a cultivated species, a situation parallel to that observed in many wild species.

LITERATURE CITED

Andersen, Edgar. 1947. Field studies of Guatemalan maize. Ann. Mo. Bot. Gard. 34:433-467.

Clausen, Jens, David D. Keck, and William Hiesey. 1948. Experimental studies on the nature of species. III. Environmental responses of climatic races of Achillea. Carnegie Inst. Wash. Publ. 581. 129 pp.

Mangelsdorf, Paul C. and James W. Cameron. 1942. Western Guatemala, a secondary center of origin of cultivated maize varieties. Harvard Bot. Mus. Leaflets 10:217-252.

Wellhausen, E.J., L.M. Roberts, and E. Hernandez X. in collaboration with P.C. Mangelsdorf. 1952. Races of maize in Mexico. Bussey Inst. of Harvard Univ., Cambridge.

APPENDIX

Table I. Distributions of yields of collections grown at approximately 75 feet elevation.

Collected from	Yield in bushels per acre 0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	Group mean
250-800'		2	3	6	2	30.6
1000-1380'		1	4			23.3
1700-2400'			2	2		29.1
2800-3000'		1	8	1		23.8
4040-4200'	2					2.5
4800-5250'	14		1	1		6.0
6000'	2					1.4
7700-8300'	4					1.2

Table II. Distributions of yields of collections grown at 5000 feet elevation.

Collected from	Yield in bushels per acre 0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	Group mean
250-1380'		2	5	8	6	1		34.9
1700-2400'			1	4	3			38.6
2800-3000'			1	7	1	2	1	39.8
4040-4200'				1	1	1		45.7
4800-5250'			1	3	7	5	2	47.3
6000'				1	1			41.7
6800-7000'			3	1				27.3
7500-7800'	1	3	2	1				19.8
8500-8800'	2	5						13.1

Table III. Distributions of yields of collections grown at 8133 feet elevation.

Collected from	Yield in bushels per acre								Group mean
	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	
380-1000'	3	1							5.7
1800-2400'	3								4.5
2800-2900'	9								4.8
4800-5250'		4	4	3	1	1		1	31.1
7700-8300'			1		3	2			44.8

Table IV. Distributions of maturity scores in collections grown at 75 feet elevation. (Scored approximately 80 days after planting).

Collection from	Mean maturity score (0 = earliest)					Group mean
	0-1	1.1-2	2.1-3	3.1-4	4.1-5	
250-800'		4	8	1		2.38
1000-1380'	2	2		1		1.68
1700-2400'			3	1		2.85
2800-3000'	6	2	2			1.34
4040-4200'				1	2	4.30
4800-5250'		1	1	5	10	3.95
7700-8300'				1	3*	4.45

* 2 of these failed to silk.

Table V. Distribution of maturity scores of collections grown at 5000 feet elevation. (Scored approximately 150 days after planting).

Collected from	Mean maturity scores (0 = earliest) 0-1	1.1-2	2.1-3	3.1-4	4.1-5	Group mean
250-1380'	4	3	9	6		2.45
1700-2400'			4	4		3.38
2800-3000'	5	3	2	2		1.71
4040-4200'				1	1	4.50
4800-5250'			2	13	3	3.94
6000'				1	1	4.50
6800-7000'	1		1	2		2.88
7500-7800'			4	2	1	3.43
8500-8800'			4	3		3.29

Table VI. Distributions of maturity scores of collections of corn grown at 8133 feet elevation. (Scored approximately 180 days after planting)

Collected from	Mean maturity scores (0 = earliest) 0-1	1.1-2	2.1-3	3.1-4	4.1-5	Group mean
1000'			3	4		3.28
1780-2400'				2	1	3.66
2800-2900'			4	3	1	3.07
4130-4200'					2	4.30
4800-5250'				2	15	4.67
6000'					2	4.70
7700-8300'			2	5		3.17

Table VII. Distribution of plant heights in collections grown at 75 feet elevation.

Collected from	Mean height in feet						Group mean
	8-8.9	9-9.9	10-10.9	11-11.9	12-12.9	13-13.9	
250-800'			2	5	2	1	11.7
1000-1380'	1	2		2			10.3
1700-2400'				1	3		11.9
2800-3000'		1	3	2	2		11.0
4040-4200'	1						8.8
4800-5250		2	1	1	6	3	11.9
6000'				1			11.8
7700-8300'				1	2	1	12.5

Table VIII. Distribution of plant heights in collections grown at 5000 feet elevation.

Collected from	Mean height in feet								Group mean
	6-6.9	7-7.9	8-8.9	9-9.9	10-10.9	11-11.9	12-12.9	13-13.9	
250-1000'		2	1	4					8.8
1700-2400'				3					9.5
2800-2900'	4	1		1	1	1			8.0
4800-5250'				1			9	3	12.4
7700-8300'				4	1	1			10.2

Table IX. Distributions of plant heights in collections of corn grown at 8133 feet elevation.

Collected from	Mean height in feet						Group mean
	3-3.9	4-4.9	5-5.9	6-6.9	7-7.9	8-8.9	
1000'	1	4	2				4.5
1780-2400'		3					4.6
2800-2900'	4	1	3		1		4.8
4130-4200'				1			6.7
4800-5250'				2	2	1	*
6000'					1		**
7700-8300'				3	4		7.0

* 12 not measured because tassels were not yet exserted when data were taken.

** 1 not measured because tassels were not yet exserted when data were taken.

Table X. Distributions of rust grades in collections of corn grown at 8133 feet elevation.

Collected from	Rust Grade (0 = no infection)						Mean
	0-.5	.6-1	1.1-1.5	1.6-2	2.1-2.5	2.6-3	
1000'				1	1	5	2.54
1780-2400'					1	2	2.67
2800-2900'	1		1		3	3	2.16
4130-4200'	2						0.20
4800-5250'	11	5				1	0.53
6000'	1	1					0.40
7700-8300'	7						0.09

Table XI. Endosperm colors of collections of Guatemalan maize on which data are presented in this report.

Collected from	Color of Grains				
	Number	White	Yellow	Mixed	Other
1000'	22	11	5	2	1 blue
1000-2000'	10	5		1	1 red
2000-3000'	16	8	3	1	1 calico
4000-5000'	23	8	4	2	1 blue; 1 red
5000-6000'	4	2	1		
6000-7000'	5	1			1 brown
7000-8000'	12	3	3	2	
8000-9000'	11	4	5		
Totals	103	42	21	8	6

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MOLECULAR WEIGHT OF TAKA-AMYLASE B[1]

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Taka-amylase B, a glucogenic amylase isolated from rice bran cultures of Aspergillus oryzae, was reported (2, 4) to have a molecular weight of 7,500 to 8,000. A peptide of such small size would be quite useful in studies relating enzyme structure and behavior to biological activity and specificity. Since there were some reservations about the molecular weight reported for Taka-amylase B (2, 4, 5), the problem of molecular size was re-evaluated.

Crude A. oryzae wheat bran kojis were obtained from Dr. Gerald Reed[3], Rohm and Haas Co., Philadelphia, Pa., and Dr. Leland A. Underkofler, Takamine Laboratory Div., Miles Laboratories, Inc., Clifton, N.J. A major portion of the amylase and maltase activities which survived purification by a modified Okazaki procedure (1, 3) were associated with fractions of relatively high molecular weight (about m.w. 40,000), as determined by ultracentrifugal analysis[4]. Similar results were obtained upon ultracentrifugation of a preparation isolated from koji obtained from Sankyo Co., Ltd., Tokyo, the source of Okazaki's starting material. The latter preparation, apparently homogeneous, judging from the sedimentation pattern (Fig. 1), had a sedimentation constant, corrected to water at 20°C, of 4.13 ± .04 Svedbergs. Assuming the particle to be spherical, a minimum molecular weight of about 33,000 has been calculated. Any corrections for possible assymmetry of the particle or for concentration dependence of the sedimentation coefficient would be in the direction of increased molecular weight. Therefore, our failure to obtain an enzyme of apparent low molecular weight was not due to the strain of A. oryzae or source of culture medium (wheat bran vs. rice bran) used for koji production.

Taka-amylase B evidently resembles various other gluc-amylases in size. Okazaki (6) has noted other resemblances and certain dissimilarities among this group of amylases.

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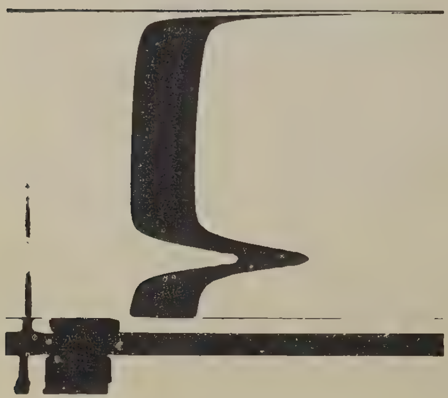

Fig. 1. Sedimentation pattern of Taka-amylase B.

REFERENCES*

1. Okazaki, Hiroshi and Shoichiro Saito. 1952. Studies on amylases of various species of molds. 6. Rates of the secondary phase of starch hydrolysis by the joint actions of crystalline taka-α-amylase and saccharogenic amylase system prepared from takadiastase. Jour. Agr. Chem. Soc. Japan, 26:447-453.
2. Okazaki, Hiroshi. 1953. Properties of saccharogenic amylase of *Aspergillus oryzae*. Ibid, 27:296.
3. _____. 1954. Studies on amylases of various species of molds. 7. Purification and properties of saccharogenic amylase of *Aspergillus oryzae* (1). Ibid, 28:48-51.
4. _____. 1954. Studies on amylases of various species of molds. 8. Purification and properties of saccharogenic amylase of *Aspergillus oryzae* (2). Ibid, 28:51-56.
5. _____. 1956. Personal communication.

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VERTICAL DISTRIBUTION OF PYTHIUM GRAMINICOLUM IN SOIL[1]

George Knaphus and W.F. Buchholtz

Knowledge of the occurrence and behavior of Pythium graminicolum Subr. in soil is basic to an understanding of its effects on the roots of crop plants grown under various cultural practices. Nothing is known about the vertical distribution of this root pathogen in soil. This report is of experiments intended to contribute such information.

Reports of occurrence of other root pathogens at various depths in the soil may be indicative of the pattern of occurrence to be expected with P. graminicolum. King and Hope (6) in 1932 found that in some soils, sclerotia of Phymatotrichum omnivorum were most prevalent at 6-24 inches and occurred at a maximum depth of 48-54 inches. Other soils were found to harbor sclerotia abundantly at a depth of 42 inches with some as deep as 84-90 inches. It was postulated that the fungus can live on roots of some trees at these extreme depths. Rogers (9) in 1942 reported sclerotia of P. omnivorum in soil at depths of 96 inches, and that these sclerotia had remained viable for up to 12 years.

On the other hand, pythiaceous fungi capable of attacking alfalfa were reported by Buchholtz (2) in 1936 as being most abundant in the upper 3-5 inches of soil. Wilhelm (12), in 1950, found Verticillium albo-atrum to be most abundant at 0-12 inches, with a gradual tapering off to only small amounts at 36 inches.

Fellows and Fiche (4) in 1934 reported that wheat plants grown in soil samples taken at a depth of 13-15 inches were somewhat less diseased by Ophiobolus graminis than those grown in samples taken nearer the surface.

Procedure

The direct isolation of Pythium graminicolum from soil samples is very difficult and is therefore probably an unreliable means of determining the presence, much less the abundance, of this pathogen in a given sample of soil (8). Wilhelm (12) used infection of susceptible tomato plants growing in it as a criterion of soil infestation by Verticillium albo-atrum. Fellows and Fiche (4) and Buchholtz (2) used wheat and alfalfa, as indicator plants for determination of soil infestation by Ophiobolus graminis and Pythium debaryanum, respectively. Samuel and Garrett (10) demonstrated that a decrease in Plasmodiophora brassicae inoculum in the soil brought a corresponding decrease in the number of infected root hairs of cabbage. Fink and Buchholtz (5) reported a definite correlation between percentage of sugar beet seedlings infected

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by Aphanomyces cochlioides in a given soil sample with extent of crop loss due to this pathogen in the field from which the sample was taken.

Crested wheatgrass is highly susceptible to Pythium graminicolum and exhibits seedling blight as a typical and predominant symptom. Furthermore, it has been shown that in some soils, P. graminicolum is the principal cause of this seedling blight (1, 3, 11).

In the experiments here reported the basic procedure for determining infestation of a sample of soil by P. graminicolum consisted in planting a specific number of crested wheatgrass seeds in soil from the sample and counting the healthy and blighted seedlings after a specified time. The percentage of blighted seedlings was considered to be an indication of the degree of soil infestation by P. graminicolum, within limits.

Soil samples were taken at five depths, 0-3, 3-6, 9-12, 15-18, and 27-30 inches, from three locations, one with corn, one with alfalfa, and the third with bluegrass sod as crop cover during and for at least two years prior to the sampling. Exacting care was devoted to digging of the three holes involved in taking the samples. No soil from upper layers was allowed to drop to lower layers. Sampling tools were cleaned and immersed in a 5 per cent formaldehyde solution prior to taking each sample. Samples were placed individually in clean new flour sacks and stored in a refrigerated room at 5°C. They were kept isolated, each from the others, to insure against mutual contamination.

The soil was Clarion loam, well drained. The three sampling sites were at approximately evuivalent locations on a slight slope to the south. Sampling was on July 19 and 20, 1950. Weather had been hot and dry prior to sampling, but was relatively cool during the sampling.

The following treatments, apportionments, and plantings were made for each of the 15 samples:

1. Unsteamed portion of sample, as collected from the field.

   a. In each of three glazed crocks of unsteamed soil were planted 100 seeds of crested wheatgrass. It was considered that such plantings should be indicative of the amount of P. graminicolum in the soil.
   b. In each of three crocks of unsteamed soil were placed five 1-sq. cm portions of an active culture of P. graminicolum, and then 100 crested wheatgrass seeds planted. Such plantings presumably indicated the suitability of the soil sample as medium for the pathogenic activity of P. graminicolum.

2. Steamed portion of sample.

   a. In each of two crocks of steamed soil were placed similar portions of an active culture of P. graminicolum, and then 100 crested wheatgrass seeds planted.
   b. In each of two crocks of steamed soil were planted 100 crested wheatgrass seeds.

Steaming of a portion of each of the 15 samples was in a separate clean sack, at 15 pounds pressure for three hours.

In preparation for planting, steamed and unsteamed portions were placed in glazed crocks, four inches in diameter, each of which had been thoroughly washed with Tide and water, rinsed, and steamed at 15 pounds pressure for one hour.

Infestation of the soil in some of the crocks was as follows: Potato-dextrose agar in Petri plates was inoculated with P. graminicolum three days before time of planting. Just prior to planting, five 1 cm square portions of such a plate culture were distributed in the soil in each "infested" crock at a depth of one inch. Five such portions of sterile agar were similarly placed in "uninfested" crocks.

The crested wheatgrass seed used in this experiment was from a lot supplied by the Iowa State College seed laboratory, with a laboratory germination of 70 per cent. The seed had been cleaned in the seed laboratory, and during counting, all light, discolored and double seeds were rejected. The 100 seeds for each crock were planted at a depth of one-half inch.

The field capacity of each soil sample was determined after the method described by Loomis and Shull (7). Each crock contained 800 grams of soil, and the soil in each crock was brought to field capacity immediately after planting and weighed and restored to that moisture content each evening thereafter.

Total of diseased and healthy seedlings were counted 21 days after planting. Seedlings severely wilted or with dead leaves were counted as diseased. After 35 days, isolations were made from the roots of six seedlings in each crock. The seedlings were carefully dug and the roots washed under a strong atomizer spray until they appeared clean. They were then dried with clean paper towels and a representative portion of each seedling root system was laid on 2 per cent agar in Petri plates. Direct observation of plates with the aid of a microscope revealed the presence or absence of lobulate sporangia typical of P. graminicolum.

The pH of the 15 soil samples was measured with a Beckman meter, with results as follows:

Sample	Sample source, area		
depth	Corn	Alfalfa	Bluegrass sod
0-3"	5.4	6.3	6.4
3-6"	5.7	6.3	6.1
9-12"	5.7	6.4	5.9
15-18"	6.0	6.6	5.9
27-30"	6.6	7.0	6.0

Diseased Crested Wheatgrass Seedlings in Soil Samples Taken at Depths to 30 inches

The number of healthy and obviously diseased crested wheatgrass seedlings in soil samples taken at depths of 0-3, 3-6, 9-12, 15-18, and 27-30 inches, from areas with corn, alfalfa, and bluegrass sod as the current and preceding crop, were counted after 21 days. The average

percentage diseased seedlings in three crocks each of unsteamed and unsteamed infested (with P. graminicolum) and two crocks each of steamed and steamed infested, for each of the 15 damples, is recorded in Table 1.

Table 1. Percentages of diseased seedlings 21 days after planting in soil samples taken at depths to 30 inches—unsteamed and steamed, without and with P. graminicolum added.

Sample area	Depth	Unsteamed	Unsteamed, P. graminicolum added	Steamed	Steamed, P. graminicolum added
Corn	0-3	20.6	31.0	1.0	34.8
	3-6	43.2	71.5	6.0	11.1
	9-12	27.6	81.0	4.8	81.0
	15-18	36.0	91.0	4.9	80.0
	27-30	8.8	90.0	1.2	90.0
Alfalfa	0-3	6.5	26.7	3.1	78.0
	3-6	27.0	38.0	5.2	94.0
	9-12	24.6	51.0	1.7	93.0
	15-18	7.5	96.5	2.1	88.0
	27-30	5.2	83.0	0.0	94.5
Bluegrass sod	0-3	6.1	79.0	0.0	1.9
	3-6	26.1	90.0	2.9	6.1
	9-12	10.4	87.5	0.0	3.2
	15-18	4.0	95.0	4.0	88.5
	27-30	0.3	86.0	0.0	87.0

Conspicuous from the data in Table 1 is the fact that there were relatively few diseased seedlings in unsteamed soil from a depth of 27-30 inches, and likewise, for the alfalfa and bluegrass sod areas, in unsteamed soil from a depth of 15-18 inches. For each respective sampling depth, there was a higher percentage of diseased seedlings in unsteamed soil from the corn area than from the alfalfa and bluegrass sod areas. Except for the 3-6 inch depth, there were more diseased seedlings in unsteamed soil from the alfalfa area than from the bluegrass sod area. For each sampling area, there were fewer diseased seedlings in the surface soil (0-3 inches) than in samples taken at depths of 3-6 inches and 9-12 inches.

In unsteamed soil with P. graminicolum added, there was in all cases a high percentage of diseased seedlings, particularly in soil samples taken at 15-18 and 27-30 inch depths. It would appear therefore, that none of the unsteamed soil samples were repressive to the pathogenic activity of P. graminicolum on crested wheatgrass roots, and that low or high incidence of disease in uninfested unsteamed soil might reflect low or high incidence of natural infestation by P. graminicolum.

On such a basis it could be concluded that P. graminicolum occurred in most abundance in the soil samples taken at a depth of 3-6 inches and that in other than those collected at 15-18 inches in the corn area, soil samples taken at that depth and at 27-30 inches were relatively free of P. graminicolum. It could be concluded furthermore that P. graminicolum occurred in most abundance and at greatest depth in the corn area and in somewhat the least abundance, and primarily in the top 12 or even six inches, in the bluegrass sod area.

Although there were a few diseased seedlings in steamed, uninfested soil, they were not in sufficient numbers to cast doubt upon the assumption that most of the diseased seedlings in unsteamed soil, without or with P. graminicolum added, and in steamed soil with P. graminicolum added, were diseased by other than seedborne pathogens.

Isolations of Pythium graminicolum from Roots of Crested Wheatgrass Seedlings in Soil Samples Taken at Depths to 30 inches

As a means of verifying that P. graminicolum was present on the roots of the crested wheatgrass seedlings grown in the unsteamed portions of soil samples collected at the various depths in the corn, alfalfa, and bluegrass sod areas, isolations were made from the roots of six seedlings in each crock. Steps in the isolation have been outlined under "Procedure." The frequencies with which lobulate sporangia typical of P. graminicolum were observed in isolation plates with roots from each soil sample are presented in Table 2.

Table 2. Frequency of occurrence of P. graminicolum in isolation plates with crested wheatgrass roots grown in soil samples taken at depths to 30 inches.

Sample area	Sample depth, inches	No. plates with P. graminicolum
Corn	0-3	6
	3-6	14
	9-12	15*
	15-18	9
	27-30	10
Alfalfa	0-3	5
	3-6	11*
	9-12	9
	15-18	4
	27-30	0
Bluegrass sod	0-3	7
	3-6	15
	9-12	14
	15-18	2
	27-30	0

*Total of 18 isolations for each soil sample except corn, 9-12 inches (16) and alfalfa, 3-6 inches (14).

The isolation results seem to confirm the observations of diseased seedlings in soil samples taken at depths of 15-18 inches and 27-30 inches, namely, P. graminicolum was recovered more frequently from roots grown in corn area samples at these depths than from roots in similar soil samples from the alfalfa and bluegrass sod areas. It is noteworthy also that for all three sampling areas there were fewer recoveries of P. graminicolum from roots grown in surface (0-3 inches) soil than from those grown in soil taken at depths of 3-6 inches and 9-12 inches.

At least to the extent indicated above the isolation results are in conformity with the relative abundance of diseased seedlings in respective soil samples.

Summary

Soil samples were collected at five depths, 0-3, 3-6, 9-12, 15-18, and 27-30 inches, from three locations, one with corn, one with alfalfa, and the third with bluegrass sod as crop cover during and at least two years prior to the sampling. Crested wheatgrass seed was planted in unsteamed, unsteamed infested (with P. graminicolum culture), steamed and steamed infested subsamples of each depth sample; percentage of diseased seedlings was determined for each subsample. An equal number of roots from each of the several unsteamed subsamples were placed on nonnutrient agar in Petri plates and the ultimate presence or absence on each plate of lobulate sporangia typical of P. graminicolum was recorded.

For the respective locations, diseased seedlings were most abundant in unsteamed soil samples taken at a depth of 3-6 inches. There were relatively few diseased seedlings in any samples taken at 27-30 inches or in samples taken at the 15-18 inch depth in the alfalfa and bluegrass sod areas. In general, frequency of recovery of P. graminicolum in isolations from roots grown in a particular soil sample was in relative conformity with percentage of diseased seedlings in that sample. P. graminicolum was not isolated from roots grown in soil samples taken at 27-30 inches in the alfalfa and bluegrass sod areas.

Evidently P. graminicolum occurred most abundantly in samples taken at 3-6 inches and very little in samples taken at 27-30 inches. At all depths, P. graminicolum was more abundant in samples from the corn area than in samples from the alfalfa and bluegrass sod areas. None of the unsteamed soil samples repressed the pathogenic activity of P. graminicolum when portions of laboratory cultures of this pathogen were incorporated in the soil.

Literature Cited

1. Andrews, E. A. 1943. Seedling blight and root rot of grasses in Minnesota. Phytopath. 33:234-239.
2. Buchholtz, W.F. 1936. The occurrence of pythiaceous parasites at different soil levels in relation to following practices. Phytopath. 26:88. (abst.)

3. Buchholtz, W.F. 1949. A comparison of gross pathogenic effects of Pythium graminicola, Pythium debaryanum and Helminthosporium sativum on seedlings of crested wheatgrass. Phytopath. 29-102-116.

4. Fellows, H., and C. H. Fiche. 1934. Effects on wheat plants of Ophiobolus graminis at different levels in the soil. Jour. Agr. Res. 49:871-880.

5. Fink, H. C., and W.F. Buchholtz. 1954. Correlation between sugar beet crop losses and greenhouse determinations of soil infestation by Aphanomyces cochlioides. Proc. Amer. Soc. Sugar Beet Tech. 8:252-259.

6. King, C.J. and Claude Hope. 1932. Distribution of the cotton root-rot fungus in soil and in plant tissues in relation to control by disinfectants. Jour. Agr. Res. 45:725-740.

7. Loomis, W.E. and C.A. Shull. 1937. Methods in Plant Physiology. McGraw-Hill Book Company, Inc., New York, N.Y.

8. McLaughlin, J.H. 1946. The effect of soil moisture and temperature upon the prevalence and activity of Pythium in soil. Ph.D. thesis, Iowa State College Library, Ames.

9. Rogers, C.H. 1942. Cotton root rot studies with special reference to sclerotia, cover crops, etc. Texas Agr. Exp. Sta. Bull. 614.

10. Samuel, G. and S.D. Garrett. 1945. The infected root-hair count for estimating the activity of Plasmodiophora brassicae Woron. in soil. Ann. Appl. Biol. 32:96-101.

11. Sprague, R. 1944. Root rots of cereals and grasses in North Dakota. N. Dak. Agr. Exp. Sta. Tech. Bull. 332.

12. Wilhelm, Stephen. 1950. Vertical distribution of Verticillium albo-atrum in soils. Phytopath. 40:368-376.

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TIME AND FREQUENCY OF RECOVERY OF PYTHIUM DEBARYANUM AND PYTHIUM GRAMINICOLUM FROM ROOTS OF GROWING BARLEY SEEDLINGS[1]

T.E. Summers and W.F. Buchholtz

Root necrosis and seed decay of barley by species of Pythium have been reported previously (3, 5, 8, 10). The prevalence of root necrosis in Iowa in 1942, 1943, and 1944 was probably associated with the decline in production of barley in Iowa during that period.

An understanding of host-parasite relations in this case involves consideration of the stage of development during which germinating seeds and growing seedlings of barley are infected by Pythium debaryanum Hesse and P. graminicolum Subr. Prior information pertinent to the latter species was limited to observations by Roldan (9) and Ho, Meredith and Melhus (8) that attack by P. graminicolum becomes apparent three to six weeks after planting of seed, and by Sprague (10) and Vanterpool and Sprague (11) that on cereals, P. arrhenomanes is abundant during June.

To acquire information concerning relative abundance of P. debaryanum and P. graminicolum on roots of barley at successive stages of seed germination and seedling development during the growing season was the objective of the work reported in this paper.

Pertinent Literature

Pythium debaryanum as a causal agent of damping-off of barley and other plants was discussed by Erikssen (3) in 1912 and the parasitism of barley roots by this pathogen was reported from Denmark by Gram and Rostrup (5) in 1922. It has since been reported many times to attack the germinating seeds and young seedlings of many plants.

A root rot of wheat and barley caused by species of Pythium was described by Asuyama (1) in 1927. Ho, Meredith and Melhus (8) state that in the greenhouse, P. graminicolum induced necrotic lesions on roots of barley which were generally noticeable when the seedlings were about a week old, but that the yellowing and curling of lower leaves characteristically caused by this pathogen began to show when the plants were three to four weeks old. Symptoms were manifest both in the greenhouse and in the field as seed decay, root necrosis, seedling blight, and stunted growth. Ho (7), however, found that only occasionally was P. graminicolum isolated from decayed seed of corn; most of the seed decay was caused by P. debaryanum. Gerhold (4) frequently isolated P. debaryanum from decaying corn seed, but not P. graminicolum.

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[1] Journal Paper No. J-3500 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. 1205. Taken from a thesis submitted by the senior author to the graduate faculty at Iowa State College for the degree, Master of Science.

The extensive observations of Sprague (10) were that with grasses in general, P. debaryanum was associated with seed decay and damping-off when such occurred in the field, particularly in the spring. On the other hand, P. arrhenomanes was associated with root browning on grass plants beyond the early seedling state. Barley was among the cereal grasses included in his observations.

In a greenhouse experiment similar to those reported here, Buchholtz (2) recovered P. debaryanum in abundance from germinating seeds of crested wheatgrass. P. graminicolum was first isolated from roots of seedlings a week after planting seed in field soil, and frequently thereafter.

In an experiment subsequent to those reported here, Haskett (6) isolated P. graminicolum from field-grown barley roots with increasing frequency during the growing season, from May 25 to July 20. However, from the first two of three successive plantings (April 21, May 3, May 13) at Kanawha, Iowa, there were only two recoveries of P. graminicolum in 720 isolations on May 3 and May 13. There was a tendency for later plantings to ultimately yield slightly higher percentages of isolations of P. graminicolum.

Experiments

A series of plantings in the greenhouse during midwinter and a series of field plantings extending from April into July of 1947 provided the germinating seeds, seedlings, and plants of barley from which the isolations were made that constitute the data for this paper.

Greenhouse experiment

Barley seeds were planted in a thoroughly mixed sample of field soil, half from an experimental corn plot at Ames and half from a similar corn plot near Kanawha, Iowa. Seed was of the variety Arivat and was essentially free of seed-borne pathogens. There were 10 seeds per four inch pot. Normal midwinter greenhouse temperatures prevailed and soil moisture was maintained by daily watering from the greenhouse tap.

Isolations from roots were made and recorded for intervals of 2, 4, 6, 8, 12, 16, 20, 24, 28, 40, 45, and 50 days after planting. Isolations were from all germinating seeds or from roots of all plants from ten pots at all times except 50 days after planting, at which time isolations were from roots of 20 plants. Isolations from recovered, ungerminated seeds were made and recorded for 2 days after planting only.

As a means of spreading out the task of isolating at the early two-day intervals, plantings were distributed over a period extending from December 23 to January 10.

Field experiment

Plantings with the same lot of disease-free Arivat barley were made on an experimental plot at Ames during the spring and summer of 1947. The soil was Webster silty clay loam. The plot was on a gentle south slope with good drainage and had been planted to oats in 1946.

Dates of regular plantings were: April 3 (hereinafter designated as A 3), April 18 (A 18), April 22 (A 22), May 7 (M 7), May 24 (M 24), and

June 16 (J 16). A small additional planting was made on July 8 which was during a period of hot, dry weather. Seeds were planted in short (2 ft.) rows in sufficient quantities to yield 75 plants per isolation date. All except the first two plantings were in randomized locations on three replicate areas on the plot.

Isolations and root-length measurements were made and recorded at intervals of 2, 4, 6, and 10 days after planting and on each succeeding tenth day until the grain matured, or the plants from late plantings were badly "fired."

Isolation procedure

Roots of seedlings (4 to 16 days after planting) were removed from the pot or from soil in the field with care. After an initial washing in tap water with the aid of a small camel's hair brush, the roots of an individual seedling were excised from the stem and seed, and washed under a stream of tap water until they showed no evidence of adhering soil particles. They were then rinsed in three changes of sterile distilled water and quickly dried on sterile paper towels. Finally they were placed in entirety under 2 per cent water (nonnutrient) agar in a Petri plate. Such plates were incubated at room temperature and examined at intervals for presence of coenocytic mycelium and sphaerosporangia or nematosporangia typical of *Pythium debaryanum* or *P. graminicolum*, respectively.

Roots of plants taken 20 or more days after planting were too abundant for plating in entirety, so three main roots from each such plant were treated in the manner described above. Germinating seeds (2 days after planting) and seeds not yet germinated after two days were washed and plated in entirety in a manner similar to that for roots.

The above time schedule for isolation procedures held for all greenhouse plantings. In field plantings, rate of seed germination and seedling and plant development was slow in early plantings, but isolation procedures were essentially the same in regard to plant size and root development.

Root measurements

Extended over-all root length was measured on all plants taken for isolation purposes from both greenhouse and field plantings. Such measurements were made after the initial root washing.

Results

Relative frequencies of recovery of *Pythium debaryanum* and *P. graminicolum* in isolations at intervals from roots and germinating seeds from the field plantings of barley are presented in chronological order in Table 1. Close observation reveals two discernible time-frequency relationships. One such relationship is to season; the other is to time after planting, perhaps to growth and stage of development of plants in the several plantings. (Mean over-all root lengths, determined at each time of isolation from the several plantings, are also recorded in Table 1.)

Table 1. Percentages of recovery of Pythium debaryanum and P. graminicolum in isolations at intervals

Planting dates	Isolation dates																				
	April										May										
April 3	5	7	9	13			23					3					13				23
P. deb. ( )	0	11	65	33			76					51					42				33
P. gram. ( )	0	0	0	0			0					39					32				69
Rt. lgth (cm)	0	0	0-0.75	3.5			9.6					11.1					11.2				16.0
April 18					20	22		24		28			8						18		
P. deb.					13	50		52		55			76						64		
P. gram.					0	0		0		0			17						31		
Rt. lgth.					0	0-1.0		2.5		7.2			8.3						9.6		
April 22								24	26	28	2					12				22	
P. deb.								27	81	64	92					75				76	
P. gram.								0	0	0	6					17				41	
Rt. lgth.								0	0-1.5	5.3	11.3					12.5				14.0	
May 7														9	11		13	17			
P. deb.														-	68		86	91			
P. gram.														-	0		2.8	11			
Rt. lgth.														0	2.5		5.2	8.8			
May 24																					
P. deb.																					
P. gram.																					
Rt. lgth																					
June 16																					
P. deb.																					
P. gram.																					
Rt. lgth.																					
July 8																					
P. deb.																					
P. gram.																					
Rt. lgth.																					

from germinating seeds and roots of barley taken from seven field plantings, April 3 to July 8.

May	June	July
	2/48, 82; 12/15, 90	
28/66, 84, 13.6	7/38, 100; 17/26, 97; 27/13, 93	
	1/68, 61; 11/33, 100; 21/32, 96	1/22, 100
27/89, 43, 11.1	6/74, 70, 17.2; 16/62, 94; 26/17, 93	6/20, 100; 16/0, 87
26/92, 2.5, 0.7; 28/85, 7, 3.3; 30/88, 0, 4.9	3/88, 14, 8.9; 13/75, 89, 9.3; 23/50, 92	3/9, 83; 13/2.8, 83; 23/0, 52
	18/68, 0, 2.1; 20/61, 9, 6.1; 22/97, 37, 7.0; 26/67, 54, 9.8	6/5, 97, 9.8; 16/0, 64; 26/0, 17
		10/18, 0, 2.5; 12/9, 4.3, 3.5; 14/7, 80, 4.8; 18/4.3, 35, 5.2; 28/0, 36, 6.9

Seasonal relationship

Pythium debaryanum was isolated with moderate frequency (up to 81 per cent in one instance) during April, with high frequency (up to 97 per cent) in May and June, and very infrequently (up to only 23 per cent) in July. P. graminicolum was isolated not at all in April, with increasing moderate to high frequency in May and June, and with declining frequency in July. These two seasonal trends are plotted, by 10-day intervals, in Figure 1.

Weather in April, May, and June was characterized by relatively frequent, sometimes abundant (especially in June) rainfall and moderate temperatures. All of July was very dry and maximum air temperatures on 11 of the 21 days after July 10 were 89°F or above.

Relationship to growth and stage of development of plants

Although growth and stage of development of barley plants in a given planting was coincident with change in season, examination of the data for the several plantings reveals for each planting a pattern of frequency of recovery, particularly of Pythium graminicolum, related to stage of plant development as indicated by mean over-all root length. For instance, there was no recovery of P. graminicolum from germinating seeds without measurable roots. In the April and May plantings, 10 per cent or more of recovery of P. graminicolum was limited to isolations from roots with mean lengths of 8.3 cm or longer. In the June and July plantings, the same percentage of recovery was from roots with mean lengths of 4.8 cm or longer.

Isolation data for all plantings have been grouped according to days after planting and so plotted in Fig. 2, along with a plotting of similar data from the greenhouse experiment. There is a striking similarity in slope of the curves from field and greenhouse data for recovery of P. graminicolum. Except for the field planting late in July, when the soil was hot and dry, there was a general tendency for increase in percentage of recovery of P. graminicolum with lapse of time after planting. There was no exception to this trend in any of the plantings even though in late plantings plant growth rate was more rapid and there was less time lapse before abundant recovery of P. graminicolum.

Except for the first field planting, there was moderate to abundant recovery of P. debaryanum from germinating seeds 2, 4, and 6 days after planting, whether or not there was measurable root growth. There was a slight tendency to isolate continuously less P. debaryanum after 20, 30, or 40 days beyond planting time, even before the failure to isolate P. debaryanum from any sized plants in July. Percentages of recovery of P. debaryanum 2 to 70 days after planting have been grouped for the several field plantings and plotted in Fig. 2, along with a plotting of similar data from the greenhouse experiment. The tendency toward negative slope after the first time increments is consistent and pronounced for the field but not for the greenhouse data. The seasonal relationship doubtless is included, but the results nevertheless were, in general, progressively less recovery of P. debaryanum from roots of field-grown barley with lapse of time beyond six or ten days after planting.

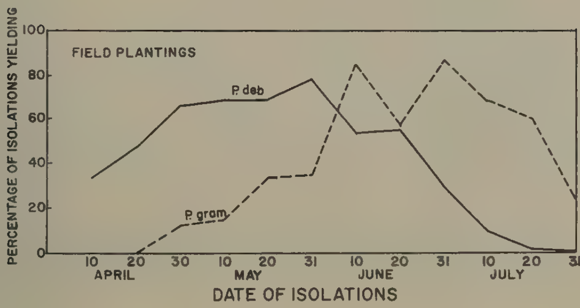

Fig. 1. Relative frequency of isolation of Pythium debaryanum and P. graminicolum, April through July, from barley seeds and roots from field plantings.

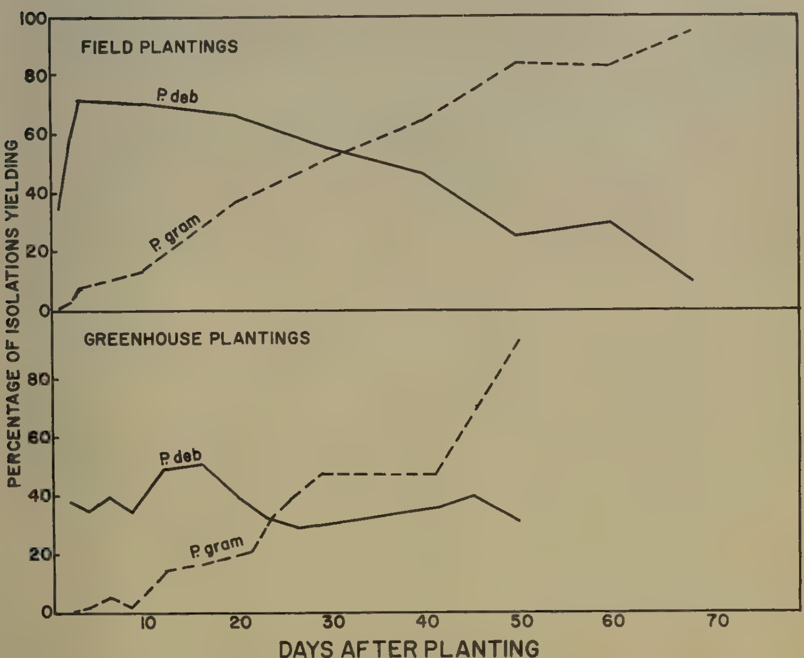

Fig. 2. Relative frequency of isolation of Pythium debaryanum and P. graminicolum from barley seeds and roots taken at intervals after planting. (Field plantings above, greenhouse plantings below.)

SUMMARY

Essentially pathogen-free Arivat barley seeds were planted in field soil in the greenhouse and in the field at intervals during the spring and early summer of 1947 (April 3 to July 8). Isolations from germinating seeds and roots of young seedlings were also at intervals, the first two days after planting.

Pythium debaryanum was isolated with moderate frequency during April, with high frequency in May and June, and very infrequently in July. P. graminicolum was isolated not at all in April, with increasing moderate to high frequency in May and June, and with declining frequency in July.

In April and May plantings, P. graminicolum was isolated at frequencies of 10 per cent or more only after average root lengths were at least 8.3 cm. In June and July plantings, such frequencies of isolation occurred only after average root lengths were at least 4.8 cm. With all field plantings, and with the greenhouse planting, there was a tendency toward increase in frequency of isolation of P. graminicolum with increase in size of plant recorded as average root length, except for isolations made after mid-July.

On the basis of frequency of isolation, it may be concluded that although occurrence of P. graminicolum in barley roots was somewhat coincident with season, P. graminicolum occurred not at all in germinating seeds but did occur and with increasing frequency in the roots of barley seedlings after they had made considerable growth, even in late plantings. Frequency of occurrence of P. debaryanum was seasonal, apparently either in or on seeds or roots.

Literature Cited

1. Asuyama, H. 1935. New diseases and pathogens reported in the year 1934 on our cultivated plants in Japan. Ann. Phytopath. Soc. Japan 4:3-4, 191-197.
2. Buchholtz, W.F. 1949. A comparison of gross pathogenic effects of Pythium graminicolum, Pythium debaryanum and Helminthosporium sativum on seedlings of crested wheat grass. Phytopath. 39:102-116.
3. Erikssen, J. 1912. Fungoid diseases of agricultural plants. (Trans. from the Swedish by Anna Molander) Bailliere, Tindall and Cox, London.
4. Gerhold, N.R. 1947. Evaluation of seed treatment fungicides on corn, oats and flax. M.S. Thesis, Iowa State College Library, Ames.
5. Gram, E. and S. Rostrup. 1922. Oversigt over Sygdomme hos Landbrugets og Havebrugets Kulturplanter i 1921. Tidskrift for Planteavl 28:185-246.
6. Haskett, W.C. 1950. Relative susceptibility of barley varieties to Pythium graminicola Subr. M.S. Thesis, Iowa State College Library, Ames.
7. Ho, W.C. 1944. Soil inhabiting fungi attacking the roots of maize. Iowa Agr. Exp. Sta. Res. Bull. 332.

8. Ho, W. C., C. H. Meredith, and I. E. Melhus. 1941. Pythium graminicola Subr. on barley. Iowa Agr. Exp. Sta. Res. Bull. 287.

9. Roldan, E.F. 1932. Pythium root rot of corn in the Philippine Islands. Phil. Agr. 21:165-176.

10. Sprague, R. 1944. Rootrots of cereals and grasses in North Dakota. N. Dak. Agr. Exp. Sta. Tech. Bull. 332.

11. Vanterpool, T.C. and R. Sprague. 1942. Pythium arrhenomanes on cereal and grasses in the Northern Great Plains. Phytopath. 32:327-329.

PUBLICATIONS OF MEMBERS OF THE STAFF OF THE IOWA STATE COLLEGE FOR THE ACADEMIC YEAR 1957-58

Certain summaries and indices are of interest in a survey of the publications of members of the staff of an educational and research institution such as the Iowa State College. The publications are listed in alphabetic order under the names of the senior authors. Junior authors are also listed alphabetically with cross reference to senior author.

SUMMARY

Number of individuals listed.	760
Number of publications.	833
Number of publications with single author	378
Number of publications with joint authorship.	455
Number of departments or fields represented in publications	53
Number of individuals who serve as editors or on the editorial staff of one or more scientific or technical periodicals	50

Individuals thus serving are: Atkins, Ayres, Barger, Bear, Biester, Black, Bolton, Buchanan, Carlander, Danielson, Davis, Diehl, Donhowe, Errington, Gardner, Getty, Gilman, Gowen, Heady, Heer, Hukill, Isely, Johnson, I.J., Kempthorne, Kenkel, Kirkham, Knight, Knott, Kuetemeyer, Kutish, Lauer, Lessel, Lockhart, Loomis,W.E., Mahlstede, McKinley, Pierre, Robinson, Rothenbuhler, Royer, Simons, Smith, F.G., Snedecor, Sprague, Swanson, P.P., Swenson, C.A., Tintner, Warning, Weber, Werkman.

INDEX TO PUBLICATIONS BY DEPARTMENTS OR FIELDS

The numbers which follow the names of the departments refer to the index number of the alphabetic list by authors.

INDEX BY RESEARCH INSTITUTES AND EXTENSION SERVICES

STAFF MEMBER PUBLICATIONS, 1957-58

AUTHORS AND PUBLICATIONS

Aasheim, T.S., joint author. See under Larson, W.E.

1. Abrams, R. and K.J. Frey. The relationship between moisture content and X-ray sensitivity of oat seeds, *Avena sativa*. Proc. Iowa Acad. Sci. 64:155-159. 1957.
2. Adams, J.E., Don Kirkham and D.R. Nielsen. A portable rainfall-simulator infiltrometer and physical measurements of soil in place. Soil Sci. Soc. Amer., Proc. 21:473-477. 1957.
3. _____, _____, and Wayne H. Scholtes. Soil erodibility and other physical properties of some Iowa soils. Iowa State Coll. Jour. Sci. 32:485-540. 1958.

Ahlrichs, J.L., joint author. See under Scott.
Aikman, J.H., joint author. See under Hendrickson.
Aikman, J.M., joint author. See under Ehrenreich.
Allen, R.S., joint author. See under Blake, Cowan, A.M., Huber, Owen, Pirchner, Ward, Wise.
Allgaier, E., joint author. See under Lauer.

4. Altman, L. B.,Jr. and L.F. Charity. Electric heating and system demand. Electrical World. 149(13):46,98. 1958.
5. _____ and Emil H. Jebe. Load characteristics of selected highly electrified Iowa farms. Agric. and Home Econ. Exp. Sta. Res. Bull. 453. 12pp. 1957.
6. Anderson, D.E., Doyle Chambers and Jay L. Lush. Studies on bovine ocular squamous carcinoma ("cancer eye"). III. Inheritance of eyelid pigmentation. Jour. Animal Sci. 16:1007-1016. 1957.
7. _____, J.L. Lush and D. Chambers. Studies on bovine ocular squamous carcinoma ("cancer eye"). II. Relationship between eye pigmentation and occurrence of cancer eye lesions. Jour. Animal Sci. 16:739-746. 1957.
8. Anderson, G.S., S. Legvold and F.H. Spedding. Superconductivity of lanthanum and some lanthanum alloys. Phys. Rev. 109:243-247. 1958.

Anderson, L.L., joint author. See under Day.

9. Anderson, Marvin A. Improving public understanding of water problems and policies. Jour. Soil and Water Cons. 13(2):61-64. 1958.

Apel, C., joint author. See under Svec.

10. Arajs, S. and S. Legvold. Comments of the Senftleben Method for the determination of the heat conductivity, the specific heat, and the viscosity of gases. Jour. Appl. Phys. 29:1001. 1958.
11. Armstrong, R.E. Iowa farm custom rates for 1958. Iowa Farm Science. 12:693-694. 1958.
12. Arnold, Floyd. Care of the dry and fresh cow. Agricultural and Home Econ. Ext. Bull. No. 249. 4pp. March, 1958.
13. _____, R. Fincham and D. Voelker. Ten tips for good milking. Agric. and Home Econ. Ext. Bull. No. 244. 2 pp. Nov., 1957.
14. Arnold, L.K. Plastics as materials of construction. Iowa Eng. Expt. Sta. Engr. Rept. No. 28. 18 pp. 1958.
15. _____. Plastics as materials of construction. Encyclopedia of Chem. Tech. 1st. Suppl. Vol. pp. 680-691. 1957.
16. _____ and P.R. Hsia. Drying fish and beef prior to solvent extraction. Jour. Agric. and Food Chem. 6:231-232. 1958.
17. _____ and R.K. Rao. Solubility of lard in aqueous ethanol. Jour. Amer. Oil Chem. Soc. 34:610-611. 1957.
18. _____, _____. Ethanol: A potential solvent for the extraction of vegetable oils. Soybean Digest. 18(5):22-23. 1958.
19. _____, _____. Alcoholic extraction of vegetable oils. IV. Solubilities of vegetable oils in aqueous 2-propanol. Jour. Amer. Oil Chem. Soc. 34:401-404. 1957.

20. _____, _____. Alcoholic extraction of vegetable oils. V. Pilot plant extraction of cottonseed by aqueous ethanol. Jour. Amer. Oil Chem. Soc. 35:277-281. 1958.

Arnrich, L., joint author. See under Brewer.

21. Aronoff, S. Kinetics of the photosynthetic incorporation of radiocarbon. in: Research in Photosynthesis. by: H. Gaffron, et al. Ed. 1. pp. 392-398. 1957. Interscience Publishers, Inc. New York.

22. _____. A simplified kinetic model of the photosynthetic assimilation of $C^{14}O_2$. in: Research in Photosynthesis. by: H. Gaffron. Ed. 1. pp. 392-398. 1957. Interscience Publishers, Inc. New York.

23. _____. Perchloric acid titrations of porphyrins in nitrobenzene. Jour. Phys. Chem. 62:428-431. 1958.

24. Arthur, I.W. How education, testing, counseling and placement can contribute to agricultural adjustment. A Basebook for Agricultural Adjustment in Iowa. Part III. pp. 31-35. Oct., 1957.

Ashton, G.C., joint author. See under Hudman, Johnson, C.W., Liu, Peo, Speer.

Atkins, D.F., joint author. See under Rogers.

25. Atkins, R.E. and K.J. Frey. Inheritance of awn barbing in two barley crosses. Agron. Jour. 49:558-560. 1957.

26. _____, J.G. Wheat, R.R. Kaltón and E.S. Dyas. Iowa grain sorphum tests, 1954-1957. Iowa State Coll., Agron. Leaflet 422. 1958.

_____, Editorial Board. Agronomy Journal.

_____, joint author. See under Wheat.

27. Atoji, M. Some new relations following from the Herglotz Theorem. Acta Crystallographica 10:464. 1957.

28. _____, K. Gschneidner, Jr., A.H. Daane, R.E. Rundle and F.H. Spedding. The structures of lanthanum dicarbide and sesquicarbide by X-ray and neutron diffraction. Jour. Amer. Chem. Soc. 80:1804-1808. 1958.

29. Ausprich, Harry. Peter Pan - A community project. Players Magazine. 34:10-11. 1957.

30. Ayres, John C. Methods for depleting glucose from egg albumen before drying. Food Tech. 12:186-189. 1958.

31. _____. The Encyclopedia of Chemistry (Supplement) - Food Preservatives pp. 133-135. 1958.

_____, joint author. See under Pirko, Walker.

_____, Member of Editorial Board. Applied Microbiology.

_____, Member of Editorial Staff. Food Technology.

Baker, D.L., joint author. See under Trapp.

Baker, R.O., joint author. See under Catron, Lewis.

32. Baker, R.S., J.E. Johnson and S.W. Fox. Incorporation of p-fluorophenylalanine into proteins of Lactobacillus arabinosus. Biochem. Biophys. Acta. 28:318-327. 1958.

33. Ball, A. Gordon. Why adjustment is difficult. Farm Policy Forum. 10:21-30. 1957.

34. _____. Factors influencing agricultural adjustment. ISC Special Rept. No. 20. A Basebook for Agricultural Adjustment, Pt. 1. pp. 28-32. 1957.

35. Ballantyne, Charles R. Conservation research - and lots of it. Jour. Soil and Water Cons. 12(4):186-188. 1957.

36. _____. What about watersheds? Iowa Farm Science. 12(3):11-13. 1957.

37. Balloun, S.L. and R.E. Phillips. Lysine and protein requirements of bronze turkeys. Poultry Sci. 36:884-891. 1957.

38. _____, _____. Interaction effects of vitamin B_{12} and pantothenic acid in breeder hen diets on hatchability, chick growth and livability. Poultry Sci. 36:929-934. 1957.

STAFF MEMBER PUBLICATIONS, 1957-58

39. Bancroft, T.A. Statistics. in The Encyclopedia Americana. 25:530-536a. 1958. Americana Corp. New York, Chicago, Washington, D.C.
40. _____. The mathematical theory of sampling. Jour. Amer. Stat. Assoc. 53: 598-599. 1958.
41. _____. Demand and supply of statisticians now and in the future: From the standpoint of colleges. The American Statistician. 12:20-21. 1958.
_____, joint author. See under Kwolek.
42. Banks, C.V., K.E. Burke, J.W. O'Laughlin and J.A. Thompson. Differential spectrophotometric determination of uranium and niobium. Analyt. Chem. 29:995-998. 1957.
43. _____ and J.W. O'Laughlin. Spectrophotometric determination of ruthenium with 1,10-phenanthroline. Analyt. Chem. 29:1412-1417. 1957.
44. _____, J.L. Spooner and J.W. O'Laughlin. Differential spectrophotometric determination of rare earths. Analyt. Chem. 30:458-462. 1958.
Barger, G.L., joint author. See under Shaw, R.H.
_____, Associate Editor. Bull. Amer. Meteorological Society.
_____, Associate Editor. Journal of Meteorology.
45. Barlett, R.H., M.H. Rice and R.H. Good, Jr. Approximations for coulomb wave functions. Annals of Physics. 2:372-383. 1957.
46. Barnes, Kenneth K. and A.M. Cowan, Jr. Simplified forage harvesters. Iowa Farm Science 12:559-561. 1957.
47. _____ and Robert C. Fincham. Yes, hay crushers can cut field risks. Iowa Farm Science 12:766-767. 1958.
_____, joint author. See under Cowan, A.M., Jr.
Barnes, R.G., joint author. See under Bray, Segel.
48. Bartell, L.S. and R.A. Bonham. The structure of ethylene. Jour. Chem. Phys. 27:1414-1415. 1957.
49. Bartholomew, W.V., W.D. Shrader and A.J. Englehorn. Nitrogen changes attending various crop ratations on Clarion-Webster soils in Iowa. Agron. Jour. 49:415-418. 1957.
_____, joint author. See under Parker.
Bartley, E.E., joint author. See under Swenson, M.J.
Barton, R.J., joint author. See under Spedding.
50. Baughman, R.W. and F.E. Nelson. Effect of penicillin upon the morphology and gram-staining characteristics of Streptococcus lactis and Streptococcus thermophilus. Jour. Dairy Sci. 41:706. 1958.
51. Bauleke, M.P. and C.M. Dodd. Effect of ammonium salts on an illitic shale. Jour. Amer. Ceramic Soc. 40(10):325-334. 1957.
52. Baumann, E.R. and J.L. Cleasby. Effect of the 1952-56 drought on Iowa impounded water supplies. Jour. Amer. Water Works Assoc. 50:233-244. 1958.
_____, joint author. See under Cleasby, Hutchinson, Morgan, Seidel.
54. Baumann, Ross V. and E.R. Duncan. Supply outlook for American agriculture. ISC Special Rept. No. 21. A Basebook for Agricultural Adjustment in Iowa, Pt. II. pp. 16-20. 1957.
_____, joint author. See under Paulsen.
55. Beal, G.M. Additional hypotheses in participation research. Rural Soc. 21:249-256. 1956.
56. _____. How does social change occur? ISC Special Rept. No. 22. A Basebook for Agricuutural Adjustment in Iowa, Pt. III. 35 pp. 1957.
57. _____ and Everett M. Rogers. Informational sources in the adoption process of new fabrics. Jour. Home Econ. 49(8):630-634. 1957.
58. _____, _____ and Joe M. Bohlen. Validity of the concept of stages in the adoption process. Rural Soc. 22(2):166-167. 1957.
_____, joint author. See under Rogers, E.M.
59. Bear, Richard S. Scholastic enthusiasm. Phi Kappa Phi Jour. 37:12-17. 1958.
_____, Editorial Board. Journal of Biophysical and Biochemical Cytology.

60. Behrendt, D.R., S. Legvold and F.H. Spedding. Magnetic properites of dysprosium single crystals. Phys. Rev. 109:1544-1547. 1958.
Bell, J. Thomas, Jr., joint author. See under Weber.
61. Benbrook, Edward A. The past, present, and probable future of parasite control for livestock. Cyanamid Internat. Vet. Bull. 1:47-50. 1957.
Beneke, R.R., joint author. See under Shepherd.
62. Bennett, W.F. and J.J. Hanway. Using soil test summaries. Better Crops with Plant Food. 41(8):26-31. 1957.
62a. Benschoter, Reba P. and D.C. Charles. Retention of classroom and television learning. Jour. Appl. Psych. 41:253-256. 1957.
Beveridge, E., joint author. See under Jebe.
Biester, H.E., Associate Editor. Cornell Veterinarian.
63. Biggs, Donald L. Cavitation as a means of cleaning silt grains. Proc. Iowa Acad. Sci. 64:382-384. 1957.
64. _____. Petrography and origin of Illinois nodular cherts. State Geological Survey of Illinois Circular. 25 pp. 1958.
65. _____. Textural variations in some Iowa limestones. Proc. Iowa Acad. Sci. Vol. 65. 1958.
Bird, E.W., joint author. See under Handwerk.
66. Black, C.A. Soil-plant relationships. John Wiley and Sons, Inc. New York. Ed. 1. 322 pp. 1957.
_____, Consulting Editor. Soil Science.
_____, Editor-in-chief. Methods of Soil Analysis.
_____, Associate Editor. Soil Science Socity of America Proceedings.
67. Blake, Duane L. Influence of high school vocational agriculture on the rate of establishment of graduates in farming. The Agricultural Education Magazine. 30:83-84. 1957.
68. Blake, J.T., N.L. Jacobson and R.S. Allen. Effectiveness of various measures in bloat therapy and prophylaxis, and the resulting influence on rumen fluid characteristics. Amer. Jour. Vet. Res. 18:756-760. 1957.
69. Blaser, R.E., R.C. Hammes, H.T. Bryant, C.M. Kincaid, W.H. Skrdla, T.H. Taylor, and W.L. Griffeth. The value of forage species and mixtures for fattening steers. Agron. Jour. 48:508-513. 1956.
70. Bochinski, Julius, Morton Smutz and F.H. Spedding. Separation of monazite rare earths by solvent extraction. Ind. and Eng. Chem. 50:157-160. 1958.
Bodensteiner, L.J., joint author. See under Pinches.
71. Bohlen, Joe M. Adjustments in the rural community. I.S.C. Special Report No. 21. A Basebook for Agricultural Adjustment in Iowa, Part II. pp. 43-47. 1957.
_____, joint author. See under Beal.
72. Bolie, V.W. An optimumly designed aircraft collision warning system. Collins Engineering Report CER-695. November, 1957.
73. _____. A gravity-seeking position indicator. Jour. Inst. of Navigation. 5(8):397-400. Winter, 1957-58.
74. _____. Generating arbitrary frequencies from a single crystal standard. Proc. of the Third Midwest Symposium on Circuit Theory - Iowa State College. May, 1958.
75. _____. Divergence from Bessel's integral in a radiation equation. Notices of the Amer. Math. Soc. 5(2):223. 1958.
76. _____. Automatic computers in industry. Proc. of the Eng. Alumni Reunion, Michigan State University. October, 1957.
77. _____. A new method for producing continuously adjustable gear ratios. Proc. of the Amer. Soc. of Mech. Eng. December, 1957.
78. _____. A radiometric inertial reference system. Military Automation. 1(5):278-281. 1957.
79. _____. Theory of scattering from a nearly transparent anomaly. Appl. Sci. Res. 6(6):422-428 (Sec.B.). 1956-57.
80. _____. Dynamics of aircraft collision hazards in turbulent air. Collins Engineering Report CER-703. Collins Radio Co. October, 1957.

81. _____. Analysis of lateral turns to avoid collisions. Collins Engineering Report CER 704. Collins Radio Co. October, 1957.
82. Bolton, John H. The reader is important. The Exponent. 70(10):22,23,26, 27. 1957.
83. _____, David R. Boylan and Danford D. Snowden. How report-writing courses serve R/D personnel. Industrial Laboratories. pp. 57-61. Oct., 1957.
_____, Editor. Iowa Engineering Experiment Station publications.
Bonham, R.A., joint author. See under Bartell.
84. Booth, Nicholas H., Donald H. Will, Lloyd C. Moss and Melvin J. Swenson. An electrical apparatus and its application in defibrillating the heart of the dog. Jour. Amer. Vet. Med. Assoc. 132(3):117-122. 1958.
_____, joint author. See under Swenson.
85. Bowlby, Roger L. Union policy toward minimum wage legislation in postwar Britain. Industrial and Labor Relations Rev. 11:72-84. 1957.
86. Bowne, John Gilbert. A multipurpose wound retractor for small animal surgery. Jour. Amer. Vet. Med. Assoc. 133:158-160. 1958.
Boyd, H.C., joint author. See under Kreitlow.
Boylan, D.R., joint author. See under Bolton, Kottwitz.
Bradford, E.C., joint author. See under Fritz.
Bragonier, W.H., joint author. See under Johnson, I.J.
87. Braun, A.C. Tissue culture as a tool for studying the development of autonomy in neoplastic plant cells. Jour. Natl. Cancer Inst. 19:753-769. 1957.
88. Bray, P.J., S. Moskowitz, H.O. Hooper, R.G. Barnes and S.L. Segel. Pure quadrupole resonance determinations of molecular charge distributions. I. Substituted quinones, quinolines, pyridines, pyrimidines, and triazines. Jour. Chem. Phys. 28:99-102. 1958.
89. Breed, Robert S. and Erwin F. Lessel, Jr. The genus Photobacterium Beijerinck. in: Bergey's Manual of Determinative Bacteriology. 7th. Ed. The Williams and Wilkins Co., Baltimore, Maryland. pp. 193-197. 1957.
90. _____, _____ and Eleanore H. Clise. The genus Pasteurella Trevisan. in: Bergey's Manual of Determinative Bacteriology. 7th. Ed. The Williams and Wilkins Co., Baltimore, Maryland. pp. 395-402. 1957.
91. Brewer, W.D. and L. Arnrich. The role of fat in the diet. Jour. Home Econ. 50:269-273. 1958.
92. Brigham, R.D. Stem lesions associated with Xanthomonas alfalfae. Phytopath. 47:309-310. 1957.
Brindley, T.A., joint author. See under Cox, Zimmack.
Bringi, N.V., joint author. See under Wenkert.
Brooks, S.N., joint author. See under Larson, W.E.
93. Brown, D.A. and R.R. Beneke. Farm consolidation in Iowa. Iowa Farm Science. 12:763-766. 1958.
Brown, H., joint author. See under Quinn.
94. Brown, L.R., R.H. Johnson, N.L. Jacobson and P.G. Homeyer. Effects of administration of oils and of penicillin on incidence and severity of bloat and certain other responses of cattle. Jour. Animal Sci. 17:374-385. 1958.
Browning, J.A., joint author. See under Wheat.
95. Bryan, John H.D. and John W. Gowen. The effects of 2560 r of X-rays on spermatogenesis in the mouse. Biological Bull. 114:271-283. 1958.
Bryant, H.T., joint author. See under Blaser.
96. Buchanan, R.E. How bacteria are named and identified. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 15-28. 1957. The Williams and Wilkins Co., Baltimore, Maryland.
97. _____. Family III. Leucotrichaceae Buchanan Fam. Nov. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 850-851. 1957. The Williams and Wilkins Co., Baltimore, Maryland.
98. _____. Family I. Beggiatoaceae Migula 1894. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 837-844. 1957. The Williams and Wilkins Co., Baltimore, Maryland

99. _____. Paraspirillum Dobell 1912. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 257-258. 1957. The Williams and Wilkins Co., Baltimore, Maryland.

100. _____. Polyangium vitellium Link 1809. Internatl. Bull. Bact. Nomen. Tax. 7:129-136. 1957.

101. _____. Nomenclature review - Type nomenclature of micro-organisms in culture. International. Bull. Bact. Nomen. Tax. 7:161-162. 1957.

102. _____. Microbiological taxa of infraspecific and infrasubspecific rank. Internatl. Bull. Bact. Nomen. Tax. 8:97-109. 1958.

103. _____, S.T. Cowan and T. Wiken. Proposal to conserve the family name Enterobacteriaceae and to designate the type genus. Internatl. Bull. Bact. Nomen. Tax. 7:165-166. 1957.

104. _____, _____, _____ and W.A. Clark. International Code of Nomenclature of Bacteria and Viruses. Ed. 1. 186 pp. 1958. Iowa State College Press.

_____, Editor. General Bacteriology Section, Biological Abstracts.

_____, Editor. International Bulletin of Bacteriological Nomenclature and Taxonomy.

_____, Editor-in-chief. Iowa State College Journal of Science.

105. Buchele, W.F. and E.V. Collins. Development of the tandem tractor. Agric. Engr. 39:232-236. 1958.

_____, joint author. See under Shaw, R.H.

106. Buchholz, M.M. Age and growth of river carpsucker in Des Moines River, Iowa. Proc. Iowa Acad. Sci. 64:589-600. 1957.

107. Buck, Griffith J. Foliar fertilization of garden roses. Amer. Rose Ann. 43:17-21. 1958.

108. Buckberg, Albert. Unions and prices. Farm Policy Forum. 10(4):14-19. 1958.

109. Budinger, R.E. and G.K. Serovy. Investigation of a 10-stage subsonic axial-flow research compressor. IV. Individual stage performance characteristics. Nat. Adv. Comm. for Aeronautics Res. Memo. E53C11. 37 pp. 1953. Declassified 6-58.

110. _____, _____. Investigation of a 10-stage subsonic axial-flow research compressor. V. Effect of reducing inlet-guide-vane turnings on over-all and inlet-stage performance. Nat. Adv. Comm. for Aeronautics Res. Memo E53H10. 37 pp. 1953. Declassified 6-58.

111. Buehler, Robert J. Confidence intervals for the product of two binomial parameters. Jour. Amer. Stat. Assoc. 52:482-493. 1957.

_____, joint author. See under Hirschfelder.

112. Buhl, Harold R. Applying creativity. Machine Design. pp. 98-103. Feb. 6, 1958.

113. Bullinger, Clarence E. Engineering economy. Ed. 3. 379 pp. 1958. McGraw-Hill.

114. Bundy, C.E. On-farm teaching. Agricultural Education Magazine. 30(1): 4-13. 1957.

115. _____. Developing farming programs of vocational agriculture students. Agricultural Education Magazine. 30(4):78-80. 1957.

116. Burchinal, Lee G. Parents' attitudes and adjustments of children. Jour. Genetic Psych. 92:69-79. 1958.

117. _____. Mothers' and fathers' differences in parental acceptance of children for controlled comparisons based on parental and family characteristics. Jour. Genetic Psych. 92:103-110. 1958.

118. _____. Similarities of parents' personality inventory and marital satisfaction scores and attitudes toward children. The Midwest Sociologist. 20:33-38. 1957.

119. _____ and Loren Chancellor. What about school-age marriages? Iowa Farm Science. 12:12-14. 1958.

120. _____, Bruce Gardner and Glenn R. Hawkes. Children's personality adjustment and the socio-economic status of their families. Jour. Genetic Psych. 92:149-159. 1958.

121. _____, _____, _____. A suggested revision of norms for the Rogers test of personality adjustment. Child Development. 29:135-139. 1958.

122. ____, Glenn R. Hawkes and B. Gardner. Marriage adjustment, personality characteristics of parents and the personality adjustment of their children. Marriage and Family Living. 19:366-372. 1957.

____, joint author. See under Hawkes.

123. Burger, O.J. and Collins Veatch. Seeding rates and yield of red clover - Timothy mixtures. Agron. Jour. 50:173. 1958.

_____, joint author. See under Coffindaffer.

Burke, K.E., joint author. See under Banks.

124. Burkhard, W.J. and J.D. Corbett. The solubility of water in molten mixtures of LiCl and KCl. Jour. Amer. Chem. Soc. 79:6361-6363. 1957.

125. Burnett, Earl and W.C. Moldenhauer. Using rainfall records as guides to predict yields of cotton on dry lands of the high and rolling plains of Texas. Texas Agric. Expt. Sta. Bull. No. MP-223. 8 pp. 1957.

126. Burns, Edward C. The importance of lymph in the metabolism of DDT in the rat. Proc., 12th. Ann. Meet. North Central Branch, Entomol. Soc. Amer. 12:62. 1957.

127. _____, Paul A. Dahm and Donald A. Lindquist. Secretion of DDT metabolites in the bile of rats. Jour. Pharm. and Exptl. Therapeutics. 121(1): 55-62. 1957.

_____, joint author. See under Lindquist.

Burroughs, W., joint author. See under Story.

128. Burrows, W.C. and Don Kirkham. Measurement of field capacity with a neutron meter. Soil Sci. Soc. Amer., Proc. 22:103-105. 1958.

Buthala, D.A., joint author. See under Mathews.

Calvin, C.B., joint author. See under Schupp.

Campbell, R.C., joint author. See under Lundvall.

Campbell, R.E., joint author. See under McKinney.

129. Carlander, Kenneth D. Symposium on evaluation of fish populations in warm-water streams. Iowa Coop. Fisheries Res. Unit. Publ. pp. 1-118. 1957.

130. _____. Some simple mathematical models as aids in interpreting the effect of fishing. Iowa State Coll. Jour. Sci. 32:395-418. 1958.

131. _____, C.J. DiCostanzo and R.J. Jessen. Sampling problems in creel census. The Progressive Fish-Culturist. 20:73-81. 1958.

_____, Associate Editor. Transactions of American Fisheries Society.

132. Carlin, Agnes F., B. Elizabeth Holl and H.W. Walker. Correlation between flavor and number of microorganisms associated with eviscerated chicken treated with chlortetracycline. Food Tech. 11:573-577. 1957.

133. Carlisle, F.J. Soil survey of Franklin County, New York. U.S. Govt. Printing Office, Washington, D.C. 75 pp. 1958.

Carlson, C. E., joint author. See under Smith, J.F.

Carlson, O.N., joint author. See under Gibson.

134. Carson, J.E. and H. Moses. Soil temperature studies. Radiological Physics Div, Semiannual Rept, ANL-5829. pp. 187-199. 1958.

135. Carter, Dennis L. A canoe trip in Webster County. Iowa Bird Life. 27:70. 1957.

136. _____. The breeding birds of Lewis, Iowa. Iowa Bird Life. 27:42-43. 1957.

137. Carter, H.O. and H.O. Hartley. A variance formula for marginal productivity estimates using the Cobb-Douglas function. Econometrica. 26:306-313. 1958.

_____, joint author. See under Halter.

138. Cassell, W.L. Determining the equivalent circuit of a transformer by matrix methods. Elect. Engr. 76(10):913-915. 1957.

139. Catron, Damon V. Life cycle swine nutrition. Animal Husbandry Leaflet 237. 5 pp. 1958.

140. _____. Nutrition of food - Source animals. Federation Proceedings. 17:756-760. 1958.

141. _____. Recent developments in swine nutrition. Maryland Nutrition Conf. 19 pp. 1958.

142. _____. Developments in swine production and feeding. Feedstuffs. 30:28-35. 1958.

143. _____. Feeding swine the modern way. Distillers Feed Conf. 13 pp. 1958.

144. _____. Series: 1. Factors that affect feed requirements. 2. Three new developments. 3. Feeding the baby pig. Pig Farming Magazine. April, May and June, 1958.

145. _____, Roy O. Baker and Paul A. Hartman. Enzymes in baby pig nutrition. Proc., Amer. Meat Inst. 9:23-47. 1957.

146. _____ and Virgil W. Hays. Soybean oil meal in modern animal nutrition. Italian Feed Conf., Rome, Italy. 20 pp. May, 1958.

147. _____ and Conwell W. Johnson. Recent developments in nutrition and management of lactating sows. Feed Age. 7:34-40. 1957.

_____, joint author. See under Hays, Hudman, Johnson, C.W., Lewis, Neagle, Peo, Quinn, Speer, Zucker.

Chamberlain, D.W., joint author. See under Kreitlow.

Chamberlin, J.W., joint author. See under Wenkert.

Chambers, D., joint author. See under Anderson, D.E.

Chancellor, L., joint author. See under Burchinal.

148. Chang, Chieh-Chien and Cheng-Ting Hsu. Solutions to Stoolman's external diffusion equation for instability of a normal shock inlet-diffuser. Jet Propulsion. 28:457-460. 1958.

149. Chapman, Orville L. and Jerrold Meinwald. Derivations of homopseudo-pelletierine: completely enolic beta-ketoesters. Jour. Organic Chem. 23:162-165. 1958.

_____, joint author. See under Meinwald.

Chapman, W.H., joint author. See under Simons.

150. Charles, Don C. Getting along with others. Ed. 1. 60 pp. 1957. Keystone Education Press.

151. _____. Adult adjustment of some deficient American children. Amer. Jour. Mental Deficiency. 62:300-304. 1957.

_____, joint author. See under Benschoter.

Cheng, E.W., joint author. See under Story.

Chiang, H.C., joint author. See under Everett.

152. Chiotti, P. and H.E. Shoemaker. Pyrometallurgical separation of uranium from thorium. Indust. and Engr. Chem. 50:137-140. 1958.

Chivers, W.H., joint author. See under Ramsey.

Clark, J.B., joint author. See under Owens.

Clark, W.A., joint author. See under Buchanan.

153. Clark, Wendell P. Effect of tension wood on seasoning and machining of eastern cottonwood. Forest Products Jour. 8(3):109-112. 1958.

154. Cleasby, J.L. and E.R. Baumann. Swimming pool accidents result in operators training course. Iowa Municipalities. pp. 17-19. March, 1957.

_____, joint author. See under Baumann, E.R.

155. Clise, Eleanore Heist and Erwin F. Lessel, Jr. The genus Ramibacterium Prévot. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 563-566. 1957. The Williams and Wilkins Co., Baltimore, Maryland.

156. _____, _____. The genus Eubacterium Prévot. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 552-560. 1957. The Williams and Wilkins Co., Baltimore, Maryland.

157. _____, _____. The genus Catenabacterium Prévot. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 560-563. 1957. The Williams and Wilkins Co., Baltimore, Maryland.

_____, joint author. See under Breed.

158. Coffindaffer, B.L. and O.J. Burger. Response of alfalfa varieties to day-length. Agron. Jour. 50:389-392. 1958.

159. _____, _____. An automatic mechanism for imposing photperiods in greenhouse research. Agron. Jour. 50:283-284. 1958.

Collins, E.V., joint author. See under Buchele.

160. Collins, Peter and Harvey Diehl. Note on 1,2-cyclodecanedioxime. Analytica Chimica Acta. 18:384. 1958.

161. Collins, Robert M. and I.T. Lathrop. The importance of on-farm instruction. Agricultural Education Magazine. 30:269-270. 1958.

Cook, J.P., joint author. See under Duke.

162. Coover, James R. and Wm. C. Moldenhauer. Some criteria for capability classification of the soils of the Southern Great Plains of Texas. Soil Sci. Soc. Amer., Proc. 21:641-644. 1957.

_____, joint author. See under Moldenhauer.

163. Corbett, J.D. and A. Hershaft. The lower oxidation states of gallium. II. The Ga_2Br_4-GaBr system. Jour. Amer. Chem. Soc. 80:1530-1532. 1958.

164. _____ and P.W. Seabaugh. Preparation of the niobium (IV) and niobium (III) iodides. Jour. Inorganic and Nuclear Chem. 6:207-209. 1958.

_____, joint author. See under Burkhard.

165. Costello, G.R., R.L. Cummungs and G.K. Serovy. Experimental investigation of axial-flow compressor stator blades designed to obtain high turning angles by means of boundary-layer suction. Nat. Adv. Comm. for Aeronautics Res. Memo. E52D18. 22 pp. 1952. Declassified June, 1958.

166. Cott, A.E. How to grow grapes. Agric. and Home Econ. Ext. Pamphlet 241. 1958.

167. _____, E.L. Denison and H.L. Lantz. Growing raspberries in Iowa. Agric. and Home Econ. Ext. Pamphlet 214. 4 pp. 1958.

168. _____, H. Gunderson and M. Shurtleff. Home orchard spray schedule. Agric. and Home Econ. Ext. Pamphlet 175. 4 pp. 1958.

169. Cowan, A.M., K.K. Barnes and R.S. Allen. Evaluation of shredded legume - grass silage. Agric. Engr. 38:588-591. 1957.

Cowan, J.C., joint author. See under McKinney.

Cowan, S.T., joint author. See under Buchanan.

170. Cox, H.C. and T.A. Brindley. Time of insecticide applications in European corn borer control. Jour. Econ. Entomol. 51(2):133-137. 1958.

171. Craig, Wilfred. Survey methods and evaluation of populations. Proc. 13th. Ann. Meet. North Central Branch Entomol. Soc. Amer. 13:68-69. 1958.

Culbertson, C.C., joint author. See under Johnson, C.W.

Cummings, R.L., joint author. See under Costello.

Currey, N.H., joint author. See under Foreman.

172. Curtice, J., H. Gilman and G.S. Hammond. A study of organosilicon free radicals. Jour. Amer. Chem. Soc. 79:4754-4759. 1957.

Daane, A.H., joint author. See under Atoji, Haefling, Spedding.

173. Dahl, A.R., R.L. Handy and D.T. Davidson. Variation of loess thickness and clay content in southern Iowa. Proc. Iowa Acad. Sci. 64:393-399. 1957.

174. Dahl, L.F. and R.E. Rundle. Polynuclear metal carbonyls. III. Infrared analysis of iron tetracarbonyl. Jour. Chem. Phys. 27:323-324. 1957.

175. Dahm, Paul A. The application and persistence of systemic insecticides in plants and animals. Proc., 12th. Ann. Meet., North Central Branch, Entomol. Soc. Amer. 12:62-63. 1957.

176. _____. Uses of radioisotopes in pesticide research. in: Advances in Pest Control Research. 1:81-146. 1957. Interscience Publishers, Inc. New York.

_____, joint author. See under Burns, Lindquist, Pant.

177. Dana, F.C. and L.R. Hillyard. Engineering problems manual. Ed. 5. 309 pp. McGraw-Hill Book Co., New York. 1958.

Daniels, R.B., joint author. See under Ruhe

Danielson, G.C., joint author. See under Morris, Redin, Shaw, W.C., Strittmaker.

_____, Honorary International Editorial Advisory Board. International Journal of the Physics and Chemistry of Solids.

178. Davey, Harold W. The proper uses of arbitration. Labor Law Jour. 9:119-126. 1958.

179. _____. The union in tomorrow's world. Farm Policy Forum. 10:32-36. 1958.

Davey, P.O., joint author. See under Pearson.

180. Davidson, D.T., R.K. Katti, M.E. Kallman and John Gurland. Correlation of the California bearing ratio and the Iowa bearing value. Amer. Soc. of Testing Materials Spec. Tech. Publ. STP No. 232 (with Spanish translation). pp. 268-298. 1957.

_____, joint author. See under Dahl, Handy, Kardoush, Nicholls, Sheeler, Sinha, Vischochil.

Davis, Arthur W., Editor. Bulletin of the Mechanics Division of A.S.E.E.

181. Day, B.N., L.N. Hazel, L.L. Anderson and R.M. Melampy. The effect of FSH and estradial benzoate on induced estrus in gilts. (Abstract). Jour. Animal Sci. 16:1104. 1957.

Dean, G.W., joint author. See under Heady.

182. Denisen, Ervin L. Principles of horticulture. Ed. 1. 509 pp. The Macmillan Co., New York. 1958.

_____, joint author. See under Cott.

183. DePuy, C.H. and D.H. Froemsdort. Electronic effects in elimination reactions. II. The E_2 reaction. Jour. Amer. Chem. Soc. 79:3710-3711. 1957.

184. _____ and R.E. Leary. Electronic effects in elimination reactions. I. Pyrolysis of acetates. Jour. Amer. Chem. Soc. 79:3705-3709. 1957.

185. _____ and E.F. Zaweski. Cyclopentene-3,5-dione. Jour. Amer. Chem. Soc. 79:3923. 1957.

186. Dicke, F.F., D.B. Leuck and L.H. Penny. The status of varietal resistance to second brood infestation of the European corn borer. Proc., 13th. Ann. Meet., North Central Branch, Entomol. Soc. Amer. 13:54-55. 1958.

_____, joint author. See under Kwolek, Penny.

187. DiCostanzo, Charles J. Growth of bluegill, Lepomis macrochirus, and pumpkinseed, L. gibbosus, of Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 32:19-34. 1957.

188. _____ and Richard L. Ridenhour. Angler harvest in the summers of 1953 to 1956 at Clear Lake, Iowa. Proc. Iowa Acad. Sci. 64:621-628. 1957.

_____, joint author. See under Carlander.

189. Diehl, Harvey and Adolf Voigt. The failure of exchange between vitamin B_{12r} and radioactive cobalt chloride. Iowa State Coll. Jour. Sci. 32:471-473. 1958.

_____, joint author. See under Jaselskis.

_____, Member, Editorial Board. Analytical Chemistry.

_____, Member, Editorial Board. Talanta.

Dietrich, J.J., joint author. See under Gilman.

190. Diggins, R.V. and C.E. Bundy. Sheep production. Ed. 1. 369 pp. Prentice-Hall, Inc., Englewood Cliffs, N.J. 1958.

_____, joint author. See under Bundy.

Dikkers, R., joint author. See under Livingston.

Dixon, H.R., joint author. See under Welp.

Doan, A.S., Jr., joint author. See under Duke.

Dodd, C.M., joint author. See under Bauleke.

Doll, C.C., joint author. See under Shaw, R.H.

Donhowe, C.E., joint author. See under Holmes.

_____, Basebook Committee. A Basebook for Agricultural Adjustment in Iowa.

191. Duke, F.R. and J.P. Cook. A nonvisual method for transport numbers in pure fused salts. Iowa State Coll. Jour. Sci. 32:35-37. 1957.

192. _____ and A.S. Doan, Jr. The solubility of water vapor in fused alkali nitrate mixtures and in lithium perchlorate. Iowa State Coll. Jour. Sci. 32:451-453. 1958.

193. _____ and M.L. Iverson. Complex ions in fused salts. Jour. Phys. Chem. 62:417-419. 1958.

194. _____ and N.C. Peterson. The role of chloride ion in the ferric-stannous reaction. Iowa State Coll. Jour. Sci. 32:89-93. 1957.

_____, joint author. See under Laity, Wadsworth.

Dumenil, L., joint author. See under White.

Duncan, E.R., joint author. See under Baumann, R.V., Heady, Shaw, R.H.

195. Dunham, Jewett. Infrared transmission of presumptive heat sensitive fenestrae and ordinary cuticle of the grasshopper. Dissertation Abstracts. 17:3131-3132. 1957.

196. Dunleavy, John M. The grasshopper as a vector of the tobacco ringspot virus in soybean. Phytopath. 47:681-682. 1957.

197. _____. Variation in pathogenicity of Diaporthe phaseolorum var. sojae to soybean. Iowa State Coll. Jour. Sci. 32:105-109. 1957.

_____, joint author. See under Kreitlow.

Dyas, E.S., joint author. See under Atkins, Wheat.

Ecker, R.E., joint author. See under Lockhart.

Eggleton, L.Z., joint author. See under Walther.

198. Ehrenkranz, Florence and Emil H. Jebe. Carbon-14 method tests to determine effectiveness of soaps and detergents. Soap and Chem. Specialists. 34:47-50,163. 1958.

199. Ehrenreich, John H. and J.M. Aikman. Effect of burning on seedstalk production of native prairie grasses. Proc. Iowa Acad. Sci. 64:205-212. 1957.

Eisch, J., joint author. See under Gilman.

Eldredge, J.C., joint author. See under Thomas.

Eldridge, A.C., joint author. See under McKinney.

Elford, C.R., joint author. See under Shaw, R.H.

200. Elleman, T.S., J.W. Reishus and D.S. Martin, Jr. The acid hydrolysis (Aquation) of the tricholoroammineplatinate (II) ion. Jour. Amer. Chem. Soc. 80:536-541. 1958.

Ellerhoff, M.A., joint author. See under Hendrickson.

Emmerson, M.A., joint author. See under Melampy.

Eness, P.G., joint author. See under Melampy.

Englehorn, A.J., joint author. See under Bartholomew, Hanway.

201. Eppright, Ercel S. Changing patterns in nutrition education. Nutrition Reviews. 15:289-292. 1957.

202. Errington, Paul L. Summer on a prairie marsh. Audubon Magazine. 59:154-157,176-177. 1957.

203. _____. Of men and marshes. Ed. 1. 150 pp. The MacMillan Co., New York. 1957.

204. _____. Of population cycles and unknowns. Cold Spring Harbor Symposia on Quantitative Biology. 22:287-300. 1957.

_____, Associate Editor. Journal of Wildlife Management.

205. Eshelman, L.R. and Earl G. Hammond. Observation on the permanganate oxidation of unsaturated esters. Jour. Amer. Oil Chem. Soc. 35:230-233. 1958.

Eskridge, P.S., joint author. See under Swenson, M.J.

Esmay, D.L., joint author. See under Gilman.

206. Everett, Travis R., H.C. Chaing and E.T. Hibbs. Some factors influencing populations of European corn borer [Pyrausta nubilalis (Hbn.)] in the North Central states -- Resistance of corn, time of planting, and weather conditions. North Central Regional Pub. No. 87, U. of Minn. Agric. Expt. Sta. Tech. Bull. 229. 63 pp. June, 1958.
207. _____, _____ and C.A. Triplehorn. Factors influencing European corn borer populations. Proc., 13th. Ann. Meet. North Central Branch Entomol. Soc. Amer. 13:51-52. 1958.
Everhart, M.E., joint author. See under Moldenhauer.
208. Everson, L.E. Purity analysis - A historical resume and a look at new frontier. Golden Jubilee Publ. of the Assoc. of Official Seed Analysts. pp. 93-95. 1958.
209. _____. Hard seeds are a good buy. Wallace's Farmer. 83:8. 1958.
210. _____. Soybeans for seed need extra care. Wallace's Farmer. 82:52-53. 1957.
211. _____. The need for extension. Golden Jubilee Publ. of the Assoc. of Offical Seed Analysts. pp. 87-88. 1958.
212. _____. The climax blowing point for the analysis of Kentucky bluegrass. Proc. Assoc. Official Seed Analysts. 47:73-78. 1957.
213. _____. The uniformity of Kentucky bluegrass seed tests using different methods and blowers. Proc. Assoc. Official Seed Analysts. 47:69-72. 1957.

214. Fabiny, Robert J. and Howard L. Hamilton. Effects of (ethylenedinitrilo) tetraacetic acid and β-2-thienylalanine on the developing down feather. The Anatomical Record. 128:545-546. 1957.
215. Facto, Louis A. Inexpensive modification of darkroom timer for time-lapse intervalometer. Jour. Biol. Photog. Assoc. 24:130. 1956.
Fahley, J.E., joint author. See under Kwolek.
216. Fairchild, M.L. and W.G. Lovely. Evaluation of insecticides for European corn borer control in 1957. Proc., 13th. Ann. Meet. North Central Branch Entomol. Soc. Amer. 13:55. 1958.
_____, joint author. See under Kwolek.
217. Fassel, V.A. and W.A. Gordon. Emission spectrometric determination of oxygen in titanium and titanium alloys. Analyt. Chem. 30:179-182. 1958.
218. _____, _____ and R.W. Tabeling. Emission spectrometric determination of oxygen in metals. Symposium on Determination of Gases in Metals -- Spec. Tech. Publ. No. 222. pp. 41-60. American Soc. for Testing Materials, Philadelphia. 1958.
_____, joint author. See under Heidel.
219. Fieller, E.C., H.O. Hartley and E.S. Pearson. Tests for rank correlation coefficients. I. Biometrika. 44:470-481. 1957.
Fincham, R., joint author. See under Arnold.
220. Flesch, Gerald D. and Harry J. Svec. New preparation for chromyl fluoride and chromyl chloride. Jour. Amer. Chem. Soc. 80:3189-3191. 1958.
221. Foreman, C.F. Vitamins for dairy cattle. Agric. and Home Econ. Ext. Bull. No. Pm-242. 2 pp. 1957.
222. _____, N.H. Currey, P.D.Homeyer and A.R. Porter. A comparison of different types of stalls for dairy cattle. Iowa State Coll. Jour. Sci. 33:43-53. 1958.
Fowler, H.S., joint author. See under Hendrickson.
223. Fox, Karl A. Agricultural income. in: A Critique of the U.S. Income and Product Accounts: Studies in Income and Wealth. National Bureau of Economic Research. Vol. 22. Ed. 1. pp. 461-469. Princeton University Press. 1958.
224. _____. Econometric analysis for public policy. Ed. 1. 289 pp. Iowa State College Press. 1958.

225. _____. Demand prospects for American agriculture. in: Iowa State Coll. Spec. Rept. No. 21. A Basebook for Agricultural Adjustment in Iowa. Part II - Prospects for the Years Ahead. pp. 10-15. Iowa State College Press. 1957.
226. _____. Effects of farm product prices on production and commercial sales. in: Policy for Commercial Agriculture - Its Relation to Economic Growth and Stability. pp. 405-429. Committee Print, Joint Economic Committee, 85th Congress, 1st Sesstion. 1957.
227. _____. Guiding agricultural adjustments. Jour. Farm Econ. 39(5):1090-1104. 1957.
228. Fox, S.W., W. Serat, T.L. Hurst, O.U. Trapp and D. Lutjens. Recoverability of phenylthiohydantions from amino acids. Jour. Amer. Chem. Soc. 79:2846-2848. 1957.
_____, joint author. See under Baker.
229. Frans, R.E., E.F. Lind and W.E. Loomis. Kinetics of growth inhibition by herbicides. Plant Physiology. 32:301-307. 1957.
230. Frederick, Lloyd R. Formation of nitrate from ammonium nitrogen in soils: 2. Effect of population of nitrifiers. Soil Science. 83:481-485. 1957.
231. Freeman, James T. and Howard Maher. A note on discrimination reaction time as a function of anxiety and intelligence. Jour. Abnormal and Social Psych. 54:134. 1957.
232. _____ and Richard I. Moren. Verbal discrimination learning as a function of anxiety and task difficulty. Proc. Iowa Acad. Sci. 64:520-523. 1957.
Freeman, T.E., joint author. See under Shurtleff.
233. French, Dexter. The schardinger dextrins. Advances in Carbohydrate Chem. 12:189-260. 1957.
234. _____. Recent developments and theoretical aspects of amylase action. Bakers's Digest. 31(4):24-36. 1957.
_____, joint author. See under Nordin, Thoma.
235. Frey, K.J., E. Ruan and S.C. Wiggans. Dry weights and germination of developing oat seeds. Agron. Jour. 50:248-250. 1958.
236. _____ and S.C. Wiggans. Tillering studies on oats. IV. Effect of rate and date of nitren fertilizer application. Proc. Iowa Acad. Sci. 64: 160-167. 1957.
_____, joint author. See under Abrams, Atkins, Ruan, Simons, Wheat, Wiggans.
Friend, D.W., joint author. See under Hudman.
237. Fritch, Kathleen C., Mary K. Schwarte and Harold S. McNabb, Jr. Observations on the effect of logging on the spread of oak wilt in the Brayton Memorial Forest, Iowa. Proc. Iowa Acad. Sci. 64:110-112. 1957.
238. Fritz, J.S. and Evelin C. Bradford. Detection of thorium and uranium. Analyt. Chem. 30:1021-1022. 1958.
239. _____ and G.S. Hammond. Quantitative organic analysis. Ed. 1. 303 pp. John Wiley and Sons, New York. 1957.
240. _____ and A.J. Moye. Titration of nitroaromatic amines as acids. Analyt. Chem. 29:1685-1688. 1957.
241. _____, _____ and Marlene J. Richard. Titration of nitroaromatic amines as acids. Analyt. Chem. 29:1685-1688. 1957.
242. _____, R.T. Oliver and D.J. Pietrzyk. Chelometric titrations using an azoarsonic acid indicator. Analyt. Chem. 30:1111-1114. 1958.
243. _____ and S.S. Yamamura. Differentiating titration of acid mixtures in acetone. Analyt. Chem. 29:1079-1084. 1957.
Froemsdort, D.H., joint author. See under DePuy.
244. Fuchs, R. and H. Gilman. Behavior of triphenylsilane, triphenylgermane and triphenyltin hydride in the presence of olefins. Jour. Organic Chem. 22:1009-1011. 1957.
Fuller, W.A., joint author. See under Shepherd.
245. Fuller, W.H. and D.R. Nielson. The influence of straw and straw-fertilizer composts on the uptake of fertilizer phosphorus by plants. Soil Sci. Soc. Amer., Proc. 21:278-282. 1957.

246. Fung, Sui-Tong Chan and John W. Gowen. Pigment-inducing potentialities of testes, ovaries and hermaphroditic (HR) gonads. Jour. Exper. Zoology. 135:5-18. 1957.
247. _____, _____. The developmental effect of a sex-limited gene in drosophila melanogaster. Jour. Exper. Zoology. 134:515-532. 1957.
_____, joint author. See under Gowen.

248. Gaarder, R.O., and E.A. Kline. What kind of ham do people want? Iowa Farm Science. 12:9-10. 1958.
249. _____, _____. What do consumers want from pork? National Provisioner. 136:59-62. 1957.
250. _____ and N.V. Strand. Use of photographs in consumer preference research. Jour. Farm Econ. 39:59-66. 1957.
251. Gadsby, Dwight Maxon. Rural banks reflect "economic weather." Iowa Farm Science. 13:10-34. 1958.
252. _____. Iowa land values rose in 1957. Iowa Farm Science. 12:699. 1958.
253. _____. Iowa bank conditions. Northwestern Banker. p. 56. June, 1958.
Gaj, B.J., joint author. See under Gilman.
Gallup, W.D., joint author. See under Woods.
254. Gardner, D. Bruce. Parent-child interaction and the theory of communication. Jour. Home Econ. 49(10):777-781. 1957.
255. _____. Research on adjustment to nursery school. Jour. Nursery Educ. 13(2):17-23. 1958.
256. _____, Glenn R. Hawkes and Damaris Pease. Development and use of research methods in child development. Jour. Home Econ. 50:201-206. 1958.
_____, Research Editor. Journal of Nursery Education.
_____, joint author. See under Burchinal, Hawkes, Pease.
257. Gardner, F.P. and S.C. Wiggans. Vegetative and floral development of oat plant as influenced by nitrogen fertilization and clipping. Proc. Iowa Acad. Sci. 64:149-154. 1957.
258. George, B.W. A comparison of several criteria used in measuring response of corn borer to resistant lines of corn. Proc. North Central Branch Entomological Soc. Amer. 13:54. 1958.
259. Gerstein, B.C., M. Griffel, L.D. Jennings, R.E. Miller, R.E. Skochdopole and F.H. Spedding. Heat capacity of holmium from 15 to 300°K. Jour. Chem. Phys. 27:394-399. 1957.
Getty, R., joint author. See under Lovell.
_____, Anatomy and Histology Editor. American Journal of Veterinary Research.
Gibbs, D.S., joint author. See under Svec.
Gibe, L.N., joint author. See under Reddy.
260. Gibson, E.D., B.A. Loomis and O.N. Carlson. Thorium-zirconium and thorium-hafnium alloy systems. Trans. Amer. Soc. for Metals. 50:348-369. 1958.
261. Gilkey, H.J. Re-proportioning of concrete mixtures for air entrainment. Title No. 54-34. Jour. Amer. Concrete Inst. 29(8):633-645. 1958.
262. _____. Test procedure to determine relative bond value of reinforcing bars (ACl 208-58). Title No. 55-1. Jour. Amer. Concrete Inst. 30(1): 1-16. 1958.
263. Gilman, H. and J.J. Dietrich. Lithium cleavages of some heterocycles in tetrahydrofuran. II. Jour. Amer. Chem. Soc. 80:380-383. 1958.
264. _____, _____. Bromonitro and related derivatives of dibenzo-p-dioxin. Jour. Amer. Chem. Soc. 80:366-368. 1958.
265. _____, _____. The direct preparation of some dihydro and other phenazine derivatives. Jour. Amer. Chem. Soc. 79:6178-6179. 1957.
266. _____, _____. Lithium cleavages of some heterocycles in tetrahydrofuran. Jour. Organic Chem. 22:851-853. 1957.

STAFF MEMBER PUBLICATIONS, 1957-58

267. _____, _____. Alkylation and related reactions of dibenzo-p-dioxin. Jour. Organic Chem. 22:1403-1406. 1957.
268. _____ and J. Eisch. The preparation and dichromate oxidation of certain 6-substituted phenanthridines. Jour. Amer. Chem. Soc. 79:4423-4426. 1957.
269. _____, _____. The chemistry and synthetic applications of the phenanthridinone system. Jour. Amer. Chem. Soc. 79:5479-5483. 1957.
270. _____ and D.L. Esmay. Stability of an ether solution of methylmagnesium iodide. Jour. Organic Chem. 22:1011-1013. 1957.
271. _____ and B.J. Gaj. Preparation and stability of some organolithium compounds in tetrahydrofuran. Jour. Organic Chem. 22:1165-1168. 1957.
272. _____ and R.D. Gorsich. Reactions of lithium with some aromatic hydrocarbons in tetrahydrofuran. Jour. Organic Chem. 23:550-551. 1958.
273. _____, _____. Cyclic organosilicon compounds. I. Synthesis of compounds containing the dibenzosilole nucleus. Jour. Amer. Chem. Soc. 80:1883-1886. 1958.
274. _____ and G.D. Lichtenwalter. The synthesis and some reactions of α-silylcarbinole. Jour. Amer. Chem. Soc. 80:2680-2682. 1958.
275. _____, _____. The addition of silyllithium compounds containing methyl and phenyl groups to benzophenone in tetrahydrofuran. Jour. Amer. Chem. Soc. 80:607-608. 1958.
276. _____, _____. Cleavage of symmetrically substituted disilanes by lithium in tetrahydrofuran. Jour. Amer. Chem. Soc. 80:608-611. 1958.
277. _____ and D.H. Miles. Disproportionation reaction of diphenylsilane in the absence of any added catalyst. Jour. Organic Chem. 23:326-328. 1958.
278. _____, _____. The preparation of cyclohexyltriphenylsilane. Jour. Amer. Chem. Soc. 80:611-613. 1958.
279. _____ and L.O. Moore. The metallation of phenoxazine and some of its derivatives. Jour. Amer. Chem. Soc. 80:2195-2197. 1958.
280. _____, _____. The preparation of some 10-substituted phenoxazines. Jour. Amer. Chem. Soc. 79:3485-3487. 1957.
281. _____ and T.S. Soddy. Metalation of aryl fluorides in tetrahydrofuran. Jour. Organic Chem. 22:1715-1716. 1957.
282. _____, _____. Reaction of phenyl- and p-tolyllithium with 1-arylisoquinolines. Jour. Organic Chem. 22:1716-1717. 1957.
283. _____, _____. Direct preparation of aryllithium compounds from aryl fluorides. Jour. Organic Chem. 22:1121-1122. 1957.
284. _____ and D.R. Swayampati. Bromination in the thianthrene system. Jour. Organic Chem. 23:313-314. 1958.
285. _____, _____ and R. O. Ranck. Cleavage studies of simple aromatic boronic acids. Jour. Amer. Chem. Soc. 80:1355-1357. 1958.
286. _____, E.A. Weipert, J.J. Dietrich and F.N. Hayes. Some oxygen-containing heterocycles as liquid scintillator solutes. Jour. Organic Chem. 23:361-362. 1958.
287. _____, _____ and F.N. Hayes. Some polyaryl derivatives of metals and metalloids as liquid scintillator solutes. Jour. Organic Chem. 23:760-762. 1958.
288. _____, _____, R.O. Ranck and F.N. Hayes. Some n-arylated heterocycles as liquid scintillator solutes. Jour. Organic Chem. 23:628-629. 1958.
289. _____, _____, T. Soddy and F.N. Hayes. Some derivatives of aza-aromatic heterocycles as liquid scintillator solutes. Jour. Organic Chem. 22:1169-1171. 1957.
290. _____ and D. Wittenberg. Addition of triphenylsilane, diphenylsilane, and phenylsilane to benzophenone. Jour. Organic Chem. 23:501-502. 1958.
291. _____, _____. The replacement of sulfur in some heterocycles by the diphenylsilylene group. Jour. Amer. Chem. Soc. 79:6339-6340. 1957.

292. _____ and E.A. Zuech. Some selective reactions of the silicon-hydrogen group with organometallic compounds. Jour. Amer. Chem. Soc. 79:4560-4561. 1957.

_____, joint author. See under Curtice, Fuchs, Hartzfeld, Meen, Santucci, Wittenberg.

_____, Editorial Board. Organic Syntheses.

293. Gilman, J.C., L.H. Tiffany and R.W. Lichtwardt. Fungi new to Iowa. Proc. Iowa Acad. Sci. 64:85-92. 1957.

294. Gless, Elmer E. and Earle S. Raun. Insecticidal control of the chicken body louse on range turkeys. Jour. Econ. Entomol. 51:229-232. 1958.

Goetz, C.A., joint author. See under Wadsworth.

295. Good, R.H., Jr. Transmission of electrons through metal surfaces. Jour. Appl. Phys. 28:1405-1408. 1957.

_____, joint author. See under Barlett, Hammer.

296. Goodman, Leo A. and H.O. Hartley. The precision of unbiased ratio-type estimators. Jour. Amer. Stat. Assoc. 53:491-508. 1958.

Gordon, W.A., joint author. See under Fassel.

297. Gorman, W.M. A note on a revised theory of expectations. Econ. Jour. (London) 67:549-551. 1957.

298. _____. Some comments on Professor Hicks' revision of demand theory. Metroeconomica. 9:167-180. 1957.

299. _____. How surprising is a chain of coincidences? Metroeconomica. 9:112-115. 1957.

Gorsich, R.D., joint author. See under Gilman, H.

300. Gowen, John W. and Sui-Tong Chan Fung. Determination of sex through genes in a major sex locus in drosophilia melanogaster. Heredity. 11(3):397-402. 1957.

301. _____ and Janice Stadler. The totipotency of all cells for typhoid resistance Salmonella typhimurium, in mice. Cytologia Proc. Internatl. Genetics Symposia. pp. 410-415. 1957.

_____, joint author. See under Bryan, Fung.

_____, Editor of Biometry Section. Biological Abstracts.

_____, Associate Editor. Genetics.

302. Grabe, Don F. Identification of soybean varieties by laboratory techniques. Proc. Assoc. of Official Seed Analysts. 47:105-119. 1957.

303. Graf, G.E. Chromosome breakage induced by X-rays, maleic hydrazine and its derivatives in relation to knob number in maize. Jour. Heredity. 48(4):155-159. 1957.

304. Greene, John C. Science and the public in the age of Jefferson. Isis. 49:13-25. 1958.

305. Griffel, M., R.W. Vest and J.F. Smith. Heat capacity of calcium from 1.8 to 4.2° K. Jour. Chem. Phys. 27:1267-1269. 1957.

_____, joint author. See under Gerstein, Hansen, W.N., Vest.

Griffeth, W.L., joint author. See under Blaser.

306. Gross, H. Douglass, C.P. Wilsie and John Pesek. Some responses of alfalfa varieties to fertilization and cutting treatments. Agron.Jour. 50:161-164. 1958.

Gschneidner, K., joint author. See under Atoji.

307. Gunderson, Harold and J.H. Lilly. Insect and rodent prospects for 1958. Iowa Farm Science. 12(7):3-4. 1958.

_____, joint author. See under Cott.

308. Gurland, John. An inequality satisfied by the gamma function. Skandivavisk Aktuarietidskrift. Haft. 3-4:171-172. 1956.

309. _____. A generalized class of contagious distributions. Biometrics. 14:229-249. 1958.

_____, joint author. See under Davidson, Rakes.

310. Guthrie, W.D. Leaf and sheath feeding resistance to the European corn borer. Proc., 13th Ann. Meet. North Central Branch Entomol. Soc. Amer. 13:52-53. 1958.

311. Gwynne, Charles S. Geology in Mini-Wakan State Park. Iowa Conservationist. 16(10):169-174. 1957.
312. _____. Geology in Nine Eagles State Park. Iowa Conservationist. 16(11): 177-183. 1957.
313. _____. Geology in Allerton Lake State Park. Iowa Conservationist. 16(12): 185-187. 1957.
314. _____. Sharon Bluffs State Park. Iowa Conservationist. 17(1):2. 1958.
315. _____. Geology in Clear Lake State Park. Iowa Conservationist. 17(4):25-32. 1958.
316. _____. Geology at Rock Greek Park. Iowa Conservationist. 18(5):33-36. 1958.
317. _____. Geology in Red Haw Hill State Park. Iowa Conservationist. 17(6): 41-48. 1958.

318. Haahr, Donald K. Two-channel transistor remote amplifier. Audio. 41(9): 46-48,84-85. 1957.
319. _____. Two-channel mixer for Auricon film camera. Audio. 41(11):36-37, 96. 1957.
320. Haas, Melvin H. Cues for broadcasters, balancing. Electronic Industries. 17(3):135. 1957.
Haber, E.S., joint author. See under Lana.
321. Haefling, J.F. and A.H. Daane. The vapor pressure of palladium. Trans., Metallurgical Soc. Amer. Inst. of Mining, Metallurgical and Petroleum Engrs. 212:115-116. 1958.
Hale, W.H., joint author. See under Story.
322. Halter, A.N., H.O. Carter and J.G. Hocking. A note on the transcendental production function. Jour. Farm Econ. 39(4):966-974. 1957.
323. Hamblin, Robert L. Group integration during a crisis. Human Relations. 11(1):67-76. 1958.
324. _____ and James A. Wiggins. Suggestibility, imitation, and recall during a crisis. The Midwest Sociologist. 20:26-32. 1957.
325. Hamilton, Howard L. Careers in animal biology. 16 pp. Iowa State College Press. 1958.
326. _____ and Gertrude W. Hinsch. The fate of the second visceral pouch in the chick. The Anatomical Record. 129:357-370. 1957.
_____, joint author. See under Fabiny, Hinsch.
327. Hammer, C.L. and R.H. Good, Jr. Wave equation for a massless particle with arbitrary spin. Phys. Rev. 108:882-886. 1957.
328. _____, _____. Quantization process for massless particles. Bull., Amer. Phys. Soc. Series II. 3:170. 1958.
329. _____ and L.J. Laslett. Electron beam control in a conventional synchrotron. Proc. 2nd. Internatl. Conf. on the Peaceful Uses of Atomic Energy. (Geneva, Switzerland). Sept. 1958.
_____, joint author. See under Laslett.
Hammes, R.C., joint author. See under Blaser.
Hammond, E.G., joint author. See under Eshelman.
Hammond, G.S., joint author. See under Curtice, Fritz.
330. Handwerk, R.L. and E.W. Bird. Determination of unoxidized tocopherols in milk fat. Jour. Dairy Sci. 41:28-33. 1958.
331. Handy, R.L. and D.T. Davidson. Portland cement contents required to stabilize eastern and western Iowa loess. Proc. Iowa Acad. Sci. 64: 276-313. 1957.
_____, joint author. See under Dahl, Lu, Vischochil.
332. Hanka, L.J. and W.R. Lockhart. Antimicrobial action as a basis for measurement of diethylstilbestrol. Jour. Bact. 75:471-473. 1958.
333. _____, _____. Microbiological assay for stilbestrol in feed supplements. Bact. Proc. 58:20. 1958.

_____, joint author. See under Melampy, Rakes.

334. Hansen, Norman J. and A.L. McComb. Growth of planted green ash, black walnut, and other species in relation to observable soil-site characteristics in southeastern Iowa. Jour. Forestry. 56:473-480. 1958.

334a. _____. Charcoal from your woodlot? Iowa Farm Science. 12:789. 1958.

335. Hansen, R.S., R.E. Minturn and D.A. Hickson. Functional group effects in the adsorption of organic compounds from aqueous solution by mercury. Jour. Phys. Chem. 61:953-957. 1957.

336. _____, Mary E. Purchase, T.C. Wallace and R.W. Woody. Extension of the vibrating jet method for surface tension measurement to jets of non-uniform velocity profiles. Jour. Phys. Chem. 62:210-214. 1958.

337. Hansen, W.N. and M. Griffel. Heat capacities of CrF_3 and $CrCl_3$ from 15° to 300° K. Jour. Chem. Phys. 28:902-907. 1958.

338. Hanson, Grant D. Bibliographies: Doctoral dissertations, English translations, research in progress. in: American-Swedish Handbook. Ed. 5. Augustana Book Concern, Rock Island, Ill. 1958.

339. Hanway, J.J. and A.J. Englehorn. Nitrate accumulation in some Iowa crop plants. Agron. Jour. 50:331-333. 1958.

340. _____ and A.D. Scott. Soil potassium - moisture relations. II. Profile distribution of exchangeable K in Iowa soils as influenced by drying and rewetting. Soil Sci. Soc. Amer., Proc. 21:501-504. 1957.

_____, joint author. See under Bennett, Scott, Vitts.

341. Hardy, Mamie Lou, Agatha Huepenbecker and Margaret Warning. Who chooses children's clothing? Iowa Farm Science. 12:731-732. 1957.

342. Hartley, H.O. Some programming problems in agricultural research. in: Proc. High Speed Computing Conf. 1957. pp. 113-124. Louisiana State University. 1958.

343. _____. Maximum likelihood estimation from incomplete data. Biometrics. 14:174-194. 1958.

344. _____. Equipping a university laboratory to satisfy the computational demand. in: The Computing Laboratory in the University. by: Preston C. Hammer. pp. 175-179. The University of Wisconsin Press, Madison, Wisc. 1957.

_____, joint author. See under Carter, G.O. Fieller, Goodman.

Hartman, P.A., joint author. See under Catron, Huber, Hudman, Lewis, Neagle.

345. Hartzfeld, H.A., R.G. Johnson and H. Gilman. Derivatives of o-phenylenedioxy-acetic acid as plant growth-regulators. Jour. Organic Chem. 22:1717-1719. 1957.

346. Haskell, Henry H. Strength properties of tension wood and typical wood in a leaning eastern cottonwood tree. Forest Products Jour. 8(1):17-22. 1958.

Hauak, J.J., joint author. See under Spedding.

347. Haugen, Arnold O. Iowa deer and fawning. Iowa Conservationist. 17:42-45. 1958.

348. _____ and Daniel W. Speake. Parturition and early reactions of white-tailed deer fawns. Jour. Mammology. 38:420-421. 1957.

Hausman, H.J., joint author. See under Kerst.

349. Hawk, Virgil B. Native grass seed. What's New in Crops and Soils? 9:8 1957.

350. Hawkes, Glenn R. Lee G. Burchinal and Bruce Gardner. Measurement of pre-adolescents' views of family control of behavior. Child Development. 28:387-392. 1957.

351. _____, _____, _____. Size of family and adjustment of children. Marriage and Family Living. 20:65-68. 1958.

352. _____, _____, _____. Pre-adolescents' views of some of their relations with their parents. Child Development. 28:393-399. 1957.

_____, joint author. See under Buchinal, Gardner, Jebe.

Haxby, R.O., joint author. See under Kerst.

Hayes, F.N., joint author. See under Gilman.

353. Hays, V.W., V.C. Speer and D.V. Catron. Application of the protein depletion-repletion technique in baby pig feeding experiments. III. Comparison of the depletion-repletion technique with conventional growth feeding trials. Jour. Nutrition. 65:63-75. 1958.

354. _____, Dean Zimmerman and D.V. Catron. Pig anemia studies. Armour Symposium on Baby Pig Anemia. 2 pp. Feb., 1958.

_____, joint author. See under Catron, Liu, Peo, Zucker.

Hazel, L.N., joint author. See under Day, Speer.

355. Heady, Earl O. Adjusting the labor force of agriculture. in: Agricultural Adjustment Problems in a Growing Economy. pp. 145-160. Iowa State Coll. Press. 1958.

356. _____. Adjusting agriculture to growth opportunities. Proc. Kan. Agric. Expt. Sta. Conf. Jan 13-15, 1958. 19 pp. Kansas State College. Agric. Expt. Sta., Manhattan, Kansas. 1958.

357. _____. Adjustment problems in the cornbelt and midwest. Policy for Commercial Agriculture in its Relation to Economic Stability, November 22, 1957. Joint Comm. of Congress Conf. Washington, D.C. 11 pp. 1957.

358. _____. Adjustment trends in Iowa. Agric. Conf. Proc. Governors Commission on Economic and Social Affairs, Des Moines, Iowa. Institute of Public Affairs, University of Iowa, Iowa City, Iowa. 19 pp. 1958.

359. _____. Application of game theory in agricultural economics. Canadian Jour. Agric. Econ. 6(1):1-15. 1958.

360. _____. Economics of cropping systems. Yearbook of Agriculture Soils. U.S.D.A., Washington, D.C. pp. 426-433. 1957.

361. _____. Farm plans by electronic brain. Cappers Farmer. pp. 7-10. Oct., 1957.

362. _____. The income and resource problem. in: Agricultural Adjustment Problems in a Growing Economy. pp. 3-18. Iowa State Coll. Press. 1958.

363. _____. The nature of agriculture adjustment problem. A Basebook for Agricultural Adjustment in Iowa. Part I: Agriculture in the Mid-fifties. Iowa Agric. Exp. Sta. Special Rep. No. 20. 3pp. 1957.

364. _____. Output in relation to input for the agricultural industry. Jour. Farm Econ. 40(2):393-406. 1958.

365. _____. Progress in adjusting agriculture to economic change. Jour. Farm Econ. 39(5):1336-1347. 1957.

366. _____. What cost for liquid or dry nitrogen? Iowa Farm Science. 12(12): 19-21. 1958.

367. _____. Organization activities and criteria in obtaining and fitting technical production functions. Jour. Farm Econ. 39:360-369. 1957.

368. _____. Adaptation of extension education and auxiliary aids to the basic economic problem of agriculture. Jour. Farm Econ. 39:112-127. 1957.

369. _____. An econometric investigation of the technology of agricultural production functions. Jour. Econometric Soc. 25:249-268. 1957.

370. _____. Economic concepts in directing and designing research for programming use of ranch resources. Jour. Farm Econ. 38:1604-1616. 1956.

371. _____. What's happening to farm size? Iowa Farm Science. 12(9):3-6. 1958.

372. _____ and Wilfred V. Candler. Linear programming methods. Ed. 1. 597 pp. Iowa State College Press. 1958.

373. _____, Gerald Dean, A.I.J. Husain and E.R. Duncan. Economic optima in soil conservation farming and fertilizer use for farms in the Ida-Monona soil are of western Iowa. Iowa Agric. Expt. Sta. Bull. 455. 19 pp. 1957.

374. _____, _____ and L.D. Loftsgard. Farm + nonfarm job = what you want? Iowa Farm Science. 12:562-564. 1957.

375. _____, Arthur Mackie and Everett G. Stoneberg. Plans for beginning farmers in southwest Iowa with comparison of farm and non-farm income opportunities. Iowa Agric. Expt. Sta. Bull. 456. 100 pp. 1958.

376. _____ and John Schnittker. Application of input-output models to agriculture. Jour. Farm Econ. 39(4):745-758. 1957.

377. _____, Wesley G. Smith and J.A. Stritzel. Liquid or dry nitrogen. Iowa Farm Science. 12(12):7-9. 1958.
_____, joint author. See under Paulsen.
_____, Chairman of Committee. Agricultural Adjustment Problems in a Growing Economy.
378. Hearn, Walter R. and Richard A. Hendry. Stereoisomerism of n,n'-oxalylbis-(alanine) derivatives. Jour. Amer. Chem. Soc. 79:5213-5217. 1957.
379. Heer, John F. and Carol A. Kuetemeyer. Center for agricultural adjustment at Iowa State College. Iowa Farm Science. 12:615-617. 1957.
_____, Editor. Iowa Farm Science.
_____, Assistant Publications Editor. Agric. and Home Econ. Expt. Sta., Cooperative Ext. Serv. in Agric. and Home Econ.
380. Hegland, R.B., M.R. Lambert, N.L. Jacobson and L.C. Payne. Effect of dietary and managemental factors on reflex closure of the esophageal groove in the dairy calf. Jour. Dairy Sci. 40:1107-1113. 1957.
381. Heidel, R.H. and V.A. Fassel. X-ray fluorescent spectrometric determination of yttrium in rare earth mixtures. Analyt. Chem. 50:176-179. 1958.
382. Hendrickson, G.O. Dowitcher recognition. Iowa Bird Life. 27:74. 1957.
383. _____. A dipper specimen at Macedonia, Iowa. Iowa Bird Life. 27:72. 1957.
384. _____. Francis LeRoy Roberts. Iowa Bird Life. 27:38-40. 1957.
385. _____, J.H. Aikman, M.A. Ellerhoff, H.S. Fowler, H.G. Hershey, F.H. Mendell, E.R. Polder and E.B. Speaker. Report of the committee on conservation. Proc. Iowa Acad. Sci. 64:50-59. 1957.
_____, joint author. See under Samuelson.
Hendry, R.A., joint author. See under Hearn.
386. Henry, R.M. and D.S. Martin, Jr. Comparative yields of (γ, 2n) and (γ, pn) processes for Fe^{54} induced by 70-Mev Bremsstrahlung. Phys. Rev. 107: 772-774. 1957.
Henson, E.R., joint author. See under Hughes.
387. Herrick, J.B. Livestock disease situation - 1958. Iowa Farm Science. 12: 684-685. 1958.
_____, joint author. See under Raun.
Hershaft, A., joint author. See under Corbett.
Hershey, H.G., joint author. See under Hendrickson.
388. Herstein, N. and M.F. Ruchte. Semi-automorphisms of groups. Proc. Amer. Math. Soc. 9:145-150. 1958.
389. Hibbs, E.T. Methods for measurement of orchard mite population density. Entomol. Soc. Amer., North Central Branch Ann. Proc. 13:64-65. 1958.
390. _____ and Lewis E. Peterson. Insecticides for the control of cutworms and Diabrotica spp. damaging melon seedlings. Entomol. Soc. Amer., North Central Branch Ann. Proc. 13:31-32. 1958.
391. _____ and Dan Wolfenbarger. Present status of the cabbage caterpillar control problems. Entomol. Soc. Amer., North Central Branch Ann. Proc. 13:34. 1958.
_____, joint author. See under Everett, Lilly.
392. Hicks, Ellis A. A new genus and species of the family Diplogyniidae (Acarina). Proc. Iowa Acad. Sci. 64:614-620. 1957.
Hickson, D.A., joint author. See under Hansen, R.S.
Hiller, M.A., joint author. See under Powell.
Hillyard, L.R., joint author. See under Dana.
393. Hinsch, Gertrude W. and Howard L. Hamilton. Characterization of alkaline phosphatase in the developing down feather. The Anatomical Record. 128:564. 1957.
_____, joint author. See under Hamilton.
394. Hippaka, T.A. Sputnik and some teaching concepts. School Shop. 17:5-6, 28-30. 1958.

395. _____. Education for peace. Indust. Arts and Voc. Ed. 47:84-90. 1958.
396. Hirschfelder, J.O., R.J. Buehler, H.A. McGee, Jr. and J.R. Sutton. Generalized equation of state for gases and liquids. Indust. and Engr. Chem. 50:375-385. 1958.
397. _____, _____, _____, _____. Generalized thermodynamic excess functions for gases and liquids. Indust. and Engr. Chem. 50:386-390. 1958.
Hocking, J.G., joint author. See under Halter.
398. Hofstad, M.S. Egg transmission of infectious sinusitis of turkeys. Avian Diseases. 1(2):165-170. 1957.
399. _____. A serological study of infectious sinusitis in turkeys. Avian Diseases. 1(2):170-179. 1957.
Holl, B.E., joint author. See under Carlin.
400. Holmes, Glen E. and Charles E. Donhowe. Educational needs and rural adjustment in Iowa. Iowa State College Spec. Rept. No. 20. A Basebook for Agricultural Adjustment in Iowa. Part I. pp. 38-41. 1957.
Homeyer, P.D., joint author. See under Foreman.
Homeyer, P.G., joint author. See under Brown, L.R., Story.
Homeyer, P.O., joint author. See under Owen.
Homme, H.A., joint author. See under Kolmer.
Hooper, H.O., joint author. See under Bray.
Hoover, J.M., joint author. See under Kardoush, Sinha.
Hopkins, A.W., joint author. See under Schlebecker.
Horner, T.W., joint author. See under Weber.
401. Howell, Herbert B. Adjustments in farm size and resources in Iowa agriculture. Iowa State College Spec. Rept. No. 21. A Basebook for Agricultural Adjustment in Iowa. Part II. pp. 31-33. 1957.
402. _____. Farm income and costs - 1956. Iowa Farm Science. 12(2):579-583. 1957.
403. Hoyt, Elizabeth E. Consumers' motivation reconsidered. Jour. Home Econ. 48:681-684. 1956.
404. _____. Consumer behavior. in: Further Discussion of Tax - Rottenberg papers. pp. 263-269. Harpers. 1958.
405. _____. Mankind: an international journal. Mankind. 2:1-7. 1957.
406. _____. El trabajador indigena in los fincas de cafe de Guatemala. in: Economia de Guatemala. 1(6):293-313. Seminario de Integracion Social Guatemalteca (Guatemalan Govt.). 1958.
Hsia, P.R., joint author. See under Arnold.
Hsu, C.T., joint author. See under Chang.
Hubbard, E.D., joint author. See under Zimmermann.
407. Huber, John T., Paul A. Hartman, Norman L. Jacobson and R. Scott Allen. Digestive enzyme activity in the young calf. Jour. Dairy Sci. 41:743. 1958.
408. Hudman, D.B., D.W. Friend, P.A. Hartman, G.C. Ashton and D.V. Catron. Digestive enzymes of the baby pig. Pancreatic and salivary amylase. Jour. Agric. and Food Chem. 5:691-693. 1957.
Hudson, D.E., joint author. See under Shaw.
Huepenbecker, A., joint author. See under Hardy.
409. Hug, D.H. and C.H. Werkman. Transamination in Rhodospirillum rubrum. Arch. Biochem. and Biophys. 72:369-375. 1957.
410. Hughes, H.D. Fifty years of crop production research. Agron. Jour. 49(12):637-643. 1957.
411. _____, E.R. Henson, D.S. Metcalfe and I.J. Johnson. Crop production. Ed. 2. 620 pp. Macmillan Co., New York. 1957.
412. Hukill, W.V. Evolution of grain drying. Agric. Engr. 38(7):526-527. 1957.
413. _____. Why crop drying pays. Cappers Farmer. 68(9):26,28-29. 1957.
414. _____. Grain moisture indicator. Agric. Engr. 38(11):808. 1957.
_____, Abstractor. Refrigeration Abstracts.

415. Hull, Dale O. and John H. Pedersen. A situation report - Heating central farrowing houses. Iowa Farm Science. 12(6):3-6. 1957.

_____, joint author. See under Schaller.

416. Hurlburt, Virgil L. Planning social change and agricultural adjustment. Iowa State College Spec. Rept. No. 22. A Basebook for Agricultural Adjustment in Iowa. Part III. pp. 14-16. 1957.

417. _____. How much for more land? Iowa Farm Science. 13(2):15-16. 1958.

418. _____. Theory of supply of farm land. Land Econ. 34:161-167. 1958.

Hurst, T.L., joint author. See under Fox.

Husain, A.I.J., joint author. See under Heady.

Hussey, Keith M., joint author. See under O'Sullivan.

419. Hutchcroft, Charles D. and Joe L. Robinson. The 1957 Iowa corn yield test. Iowa State Agric. Expt. Sta.and Ext. Serv. Bull. No. P-124. 32 pp. 1958.

420. Hutchinson, Gary D. and E. Robert Baumann. Variations of sewage flow in a college town. Sewage and Indust. Waters. 30:157-163. 1958.

421. Isely, Duane. Leguminosae of the north-central United States. III. Mimesoideae and Caesalpimioideae. Iowa State Coll. Jour. Sci. 32:355-393. 1958.

422. _____. Research and seed technology. Assoc. of Official Seed Analysts, Golden Jubilee Publ. pp. 72-74. 1958.

423. _____. Vigor tests. Proc., Assoc. of Official Seed Analysts. 47: 176-182. 1957.

_____, Editor. Golden Jubilee Publication, Association of Official Seed Analysts.

Iverson, M.L., joint author. See under Duke.

Jackson, B.G., joint author. See under Wenkert.

Jacobson, N.L.,joint author. See under Blake, Brown,L.R., Hegland, Huber, McKinney, Owen, Pirchner, Wise.

Jacobson, P., joint author. See under Schaller.

Jarvis, J.G., joint author. See under Wheat.

424. Jaselskis, Bruno and Harvey Diehl. Reversible uptake of oxygen by vitamin B_{12a}. Jour. Amer. Chem. Soc. 80:2147-2167. 1958.

425. _____,_____. Reversible oxygenation of vitamin B_{12a}. Instrument Soc. Amer., Natl. Conf. Instrumental Methods of Analysis. Paper No. AI57-3-2. 1957.

426. Jebe, Emil, Elizabeth Beveridge, G.R. Hawkes, Fannie Potgieter, Opal Roberson. How to study consumer satisfaction with children's clothing made of different textile fibers. Jour. Home Econ. 50:213-218. 1958.

_____, joint author. See under Ehrenkranz.

427. Jennings, L.D., R.M. Stanton and F.H. Spedding. Heat capacity of terbium from 15° to 350°K. Jour. Chem. Phys. 27:909-913. 1957.

_____, joint author. See under Gerstein.

Jessen, R.J., joint author. See under Carlander.

428. Johnson, C.W., V.C. Speer, G.C. Ashton, C.C. Culbertson and D.V. Catron. Supplementary plane of nutrition for sows fed corn silage. Jour. Animal Sci. 16:600-606. 1957.

429. _____,_____, C.C. Culbertson and D.V. Catron. Corn silage for sows. Iowa Farm Science. 12(1):17-19. 1957.

_____, joint author. See under Catron.

Johnson, H.P., joint author. See under Schwab.

430. Johnson, I.J. and W.H. Bragonier. Crop varieties for 1958. Iowa Farm Science. 12(1):13-16. 1958.

_____, joint author. See under Hughes, Whitely.

_____, Associate Editor. Agronomy Journal.
Johnson, J.E., joint author. See under Baker.
Johnson, R.G., joint author. See under Hartzfeld.
Johnson, R.H., joint author. See under Brown, L.R.
431. Jones, Ethel B. Unions and farm workers. Farm Policy Forum. 10:20-24. 1958.
432. Jones, L. Meyer. Antinematodal drugs. in: Advances in Veterinary Science. 3:354-395. Academic Press. 1957.
433. _____. Veterinary pharmacology and therapeutics. Ed. 2. 944 pp. Iowa State College Press. 1957.
Jones, W.G., joint author. See under Swenson, M.J.
434. Junk, G. and H.J. Svec. The presence of N_3^+ and N_4^+ in the mass spectra of molecular nitrogen. Jour. Amer. Chem. Soc. 80:2908. 1958.

435. Kaldor, Donald R. Adjustment in a dynamic economy. Farm Policy Forum. pp. 2-11. Fall, 1957.
436. _____. Adjustment problems in a progressive economy. Iowa State College Spec. Rept. No. 20. 7 pp. 1957.
437. _____. Crop controls and interregional competition. Farm Policy Forum. pp. 8-17. Summer, 1957.
438. _____. Farm policy objectives, a setting for the parity question. in: Policy for Commercial Agriculture. 8 pp. Joint Economic Committee, 85th. Congress, 1st. Session. November, 1957.
439. _____. Impact of the conservation reserve on resource adjustments in agriculture. Jour. Farm Econ. 39(5):1148-1156. 1957.
440. _____. Inter-industry adjustments in a progressive economy. in: Iowa State College Spec. Rept. No. 20, Iowa Agriculture in the Mid-Fifties. pp. 10-16. Iowa State College Press. 1957.
Kallman, M.E., joint author. See under Davidson.
Kalti, R.K., joint author. See under Davidson.
Kalton, R.R., joint author. See under Atkins, Scholl.
441. Kardoush, F.B., J.M. Hoover and D.T. Davidson. Stabilization of loess with a promising quaternary ammonium chloride. Highway Research Board Proc. (NAS-NRC Publication 542). 36:736-754. 1957.
442. Katsumori, H. Mass levels and relative parities of baryons. Phys. (Japan). 19:343-344. 1958.
443. _____. Mass difference Σ^+, Σ^- and Σ^0 hyperons. Phys. (Japan). 18:803-806. 1957.
444. _____. Anomalous magnetic moments of hyperons and mirror theorem. Phys. (Japan). 18:375-382. 1957.
Keating, F.E., joint author. See under Moldenhauer.
445. Kehlenbeck, Dorothy. Chronology of important events of the first 100 years. Iowa State College Library. 23 pp. 1958.
446. Kelton, Leonard A. The use of the mate genitalia in the classification of the Miridae. Proc. 12th Ann. Meet. North Central Branch Entomological Soc. Amer. 12:29-30. 1957.
447. Kempthorne, O. (Book Review) Experimental Designs, by W.G. Cochran and G.M. Cox. Ed. 2. John Wiley and Sons, Inc. New York. Agron. Jour. 50: 115. 1958.
448. _____. (Book Review) Experimental Designs, by W.G. Cochran and G.M. Cox. Ed. 2. John Wiley and Sons, Inc. New York. Proc., Soil Sci. Soc. Amer. 22:187. 1958.
449. _____. An introduction to genetic statistics. Ed. 1. 545 pp. John Wiley and Sons, Inc., New York; Chapman and Hall, Ltd., London. 1957.
450. _____. The contributions of statistics to agronomy. in: Advances in Agronomy. 9:177-204. Academic Press, Inc. New York. 1957.
_____, Member of Editorial Board. Biometrics.

451. Kenkel, William F. Influence differentiation in family decision making. Sociology and Social Research. 42:18-25. 1957.

452. _____. A survey of family life education in Iowa high schools. Marriage and Family Living. 19:379-381. 1957.

_____, Associate Editor. Deltan (Sociological Honorary Society Journal).

_____, Abstracter. Sociological Abstracts.

453. Kerst, D.W., H.J. Hausman, R.O. Haxby, L.J. Laslett, F.E. Mills, T. Ohkawa, F.L. Peterson, A.M. Sessler, J.N. Snyder and W.A. Wallenmeyer. Operation of a spiral sector fixed field alternating gradient accelerator. Review of Scientific Instruments. 28:970-971. 1957.

Kincaid, C.M., joint author. See under Blaser.

454. Kirkham, Don. Theory of seepage into an auger hole above an impervious layer. Soil Sci. Soc. Amer., Proc. 22:204-208. 1958.

455. _____. Theory of land drainage, the ponded water case. in: Drainage of Agriculture Lands. Ed. 1. pp. 139-181. American Society of Agronomy. (Monograph series, vol. 7) 1957.

456. _____. Graphs and formulas for zeros of cross product Bessel functions. Jour. Math. and Phys. 36:371-377. 1958.

_____, joint author. See under Adams, Burrows, Schwab, Willis, W.O.

_____, Consulting Editor. Soil Science.

Kirkpatrick, M.E., joint author. See under Rogers.

457. Kitagawa, Tosio. Some aspects of stochastically approximative analysis. Bull. Math. Stat. (Japan). 6:109-129. 1956.

Kline, E.A., joint author. See under Gaarder.

458. Knight, Harry H. Forty years of progress on the classification of family Miridae (Hemiptera). Proc., 12th. Ann. Meet. North Central Branch Entomol. Soc. Amer. 12:27. 1957.

_____, Section Editor (Hemiptera). Biological Abstracts.

459. Kolmer, Lee. Marketing adjustment and extension eduction. Jour. Farm Econ. 39:1693-1697. 1957.

460. _____. Programs for expanding domestic demand for farm products. Iowa State College Spec. Rept. No. 21. pp. 34-39. 1957.

461. _____, H.A. Homme and G.W. Ladd. Spray drying costs in low volume milk plants. Iowa State Coll. Spec. Rept. No. 19. 12pp. 1957.

Knott, Oliver A., Editorial Director, I.C.I.A. Seed News.

462. Kottwitz, F.A. and D.R. Boylan. Prediction of resistance in constant-pressure cake filtration. Amer. Inst. Chem. Engr. Jour. 4(2):175-180. 1958.

463. Kozicky, Edward L. Estimation of August quail populations. Iowa Bird Life. 27:63-69. 1957.

464. Krasnoselśkii, M.A. and H.P. Thielman. Some problems of nonlinear analysis. Amer. Math. Soc. Translations, Series 2. 10:345-409. 1958.

465. Kreitlow, K.W., Helen C. Boyd, D.W. Chamberlain and J.M. Dunleavy. A bibliography of viruses infecting soybean. Plant Dis. Reporter. 41: 579-588. 1957.

Kuetemeyer, C.A., joint author. See under Heer.

_____, Associate Editor. Iowa Farm Science.

_____, Publications Assistant. Research Publications, Agric. and Home Econ. Expt. Sta.

466. Kutish, Francis A. The current situation in agriculture. Iowa State College Spec. Rept. No. 20. in: A Basebook for Agricultural Adjustment in Iowa. Part I. pp. 5-9. 1957.

467. _____. Farm outlook. Iowa Farm Science. 12(1-10). July 1957 - April, 1958.

468. _____ and Thomas S. Rackham. Farm outlook. Iowa Farm Science. 12(11):803. 1958.

_____, Editor. Farm Policy Forum.

_____, Outlook Editor. Iowa Farm Science.

469. Kutkuhn, Joseph H. The plankton of North Twin Lake, with particular reference to the summer of 1955. Iowa State Coll. Jour. Sci. 32:419-450. 1958.

470. _____. Notes on the precision of numerical and volumetric plankton estimates from small-sample concentrates. Limnology and Oceanography. 3:69-83. 1958.

471. Kwolek, W.F., F.F. Dicke and T.A. Bancroft. Infestation indices for evaluating European corn borer damage. Proc., 13th. Ann. Meet., North Central Branch Entomol. Soc. Amer. 13:53. 1958.

472. _____, J.E. Fahey, W.G. Lovely and M.L. Fairchild. Statistics in residue studies. Proc., 13th. Ann. Meet., North Central Branch Entomol. Soc. Amer. 13:78. 1958.

473. Ladd, G.W. Biases in certain production indexes. Jour. Farm Econ. 39(1): 75-85. 1957.

474. _____. Farm income and the supply of agricultural products. Jour. Farm Econ. 39:865-880. 1957.

_____, joint author. See under Kolmer.

Laguros, J.G., joint author. See under Lu.

475. Laity, R.W. and F.R. Duke. Transport numbers in pure fused salts. Lead chloride, lead bromide, thallous chloride and silver nitrate. Jour. Electrochemical Soc. 105:97-99. 1958.

476. Laffoon, Jean L. On the inadvisability of including new nomenclatural information in abstracts. Systematic Zoology. 6:109-111. 1957.

Lambert, M.R., joint author. See under Hegland.

477. Lana, E.P., E.S. Haber and C.C. Li. Comparison of linecrosses with inbreds and linecross hybrids with single cross hybrids in sweet corn. Proc. Amer. Soc. Hort. Sci. 70:297-307. 1957.

_____, joint author. See under Mahlstede.

Lantz, H.L., joint author. See under Cott.

Larson, D., joint author. See under Willis, W.O.

478. Larson, W.E., S.N. Brooks, T.S. Aasheim and A.H. Post. Irrigated crop rotations at the Huntley Branch Station. Montana Agric. Expt. Sta. Bull. 535. 78 pp. 1958.

479. _____ and F.W. Schaller. Spacing of level terraces in western Iowa. Agric. Engr. 39:20-23. 1958.

480. _____ and W.O. Willis. Light, soil temperature, soil moisture and alfalfa-red clover distribution between corn rows of various spacings and row directions. Agron. Jour. 49:422-426. 1957.

_____, joint author. See under Parker.

481. Laslett, L. Jackson. Field of an electrostatic multipole. Amer. Jour. Phys. 26(6). Sept., 1958.

482. _____ and Charles L. Hammer. Prompt destruction of the electron beam in a conventional synchrotron. Bull. Amer. Phys. Soc. Series II. 3(3): 180. 1958.

483. _____, A.M. Sessler and J.N. Snyder. Computational study of a spirally ridged FFAG accelerator. Bull. Amer. Phys. Soc. Series II. 2(7):337. 1957.

_____, joint author. See under Hammer, Kerst.

Lasley, E.L., joint author. See under Speer.

484. Lathrop, Irvin T. Inexpensive visual aid. Nat. Educ. Assoc. Jour. 47:52. 1958.

485. _____. Silk screening on cloth. School Shop. 17:56. 1958.

_____, joint author. See under Collins.

486. Lauer, A.R. A criterion scale for classification of automobile drivers. Proc. Iowa Acad. Sci. 64:542-545. 1957.

487. _____, W. Virtus and E. Allgaier. Development of a criterion of driving performance. Proc. Highway Res. Board Bull. 172. pp. 1-8. 1957.

_____, Editorial Staff. Jour. of Motor and Perceptual Skills.

Leary, R.E., joint author. See under DePuy.

Legvold, S., joint author. See under Anderson, G.S., Arajs, Behrendt, Rhodes.

488. Lessel, Erwin F., Jr. The genus Selenomonas von Prowazek. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 258-260. The Williams and Wilkins Co., Baltimore, Maryland. 1957.

489. _____. The genus Myconostoc Cohn. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 260-261. The Williams and Wilkins Co., Baltimore, Maryland. 1957.

490. _____. The family Vitreoscillaceae Pringsheim 1949. in: Bergey's Manual of Determinative Bacteriology. Ed. 7. pp. 844-850. The Williams and Wilkins Co., Baltimore, Maryland. 1957.

_____, joint author. See under Breed, Clise.

_____, Assistant to the Editors. Bergey's Manual of Determinative Bacteriology.

Leuck, D.B., joint author. See under Dicke.

491. Levine, H.B. Equations for a lattice gas. II. Multi-component systems. Jour. Chem. Phys. 27:335-342. 1957.

492. Lewis, Charles J., Paul A. Hartman, C.H. Liu, Roy O. Baker and D.V. Catron. Digestive enzymes of the baby pig. Pepsin and trypsin. Jour. Agric. and Food Chem. 5:687-690. 1957.

Li, C.C., joint author. See under Lana.

Lichtenwalter, G.D., joint author. See under Gilman.

493. Lichtwardt, R.W. An enterobryus occurring in the milliped Scytonotus granulatus (Say). Mycologia. 49:734-739. 1957.

494. _____. Enterobryus attenuatus from the Passalid beetle. Mycologia. 49: 463-474. 1957.

_____, joint author. See under Gilman.

495. Lilly, J.H. Gibberellins as seed treatments. Proc., 13th Ann. Meet. North Central Branch Entomol. Soc. Amer. 13:16-17. 1958.

496. _____ and E.T. Hibbs. The status of Nematode research in the North Central states. Entomol. Soc. Amer., North Central Branch Ann. Proc. 13:57-58. 1958.

_____, joint author. See under Gunderson, Long.

Lind, E.F., joint author. See under Frans.

497. Lindquist, D.A., E.C. Burns, C.P. Pant and P.A. Dahm. Fate of P^{32} - labeled Bayer 21/199 in the white rat. Jour. Econ. Entomol. 51(2): 204-206. 1958.

498. _____ and P.A. Dahm. Some chemical and biological experiments with Thiodan. Jour. Econ. Entomol. 50(4):483-486. 1957.

_____, joint author. See under Burns.

499. Liu, C.H., G. Ashton, V.W. Hays. Vitamin A content in the regenerating liver of rats. Amer. Jour. Physiology. 193:439-442. 1958.

_____, joint author. See under Lewis, Peo.

500. Livingston, A.R., E. Mangotich and R. Dikkers. Flexural strength of hollow unit concrete masonry walls in the horizontal span. Iowa State College Bull., Engr. Rept. No. 29. 18 pp. 1958.

501. _____, _____, _____. Flexural strength of hollow unit contrete masonry walls in the horizontal span. National Concrete Masonry Assoc. 18 pp. 1958.

502. Lockhart, W.R. Interconversion of base 10 and base 2 logarithms. Canad. Jour. Microbiology. 4:421-423. 1958.

503. _____ and R.E. Ecker. Apparatus for independent control of aeration rates in a series of cultures. Appl. Micro. 6:93-96. 1958.

_____, joint author. See under Hanka.

_____, Assistant Section Editor. Biological Abstracts.
Loftsgard, L.D., joint author. See under Heady.
504. Long, W.H. and J.H. Lilly. Wireworm behavior in response to chemical seed treatments. Jour. Econ. Entomology. 51(3):291-295. 1958.
Loomis, B.A., joint author. See under Gibson.
505. Loomis, W.E. and W.M. Struve. Vegetation control on Iowa roadbeds - 1957. Amer. Rlwy. Engrs. Assoc. Bull. 542:836-843. 1958.
_____, joint author. See under Frans, Struve.
_____, Plant Physiology Editor. Biological Abstracts.
506. Lorch, Fred W. Hawaiian feudalism and Mark Twain's A Connecticut Yankee in King Arthur's Court. Amer. Lit. 30:50-56. 1958.
507. Lovel, James E. and Robert Getty. The hair follicle, epidermis, dermis, and skin glands of the dog. Amer. Jour. Vet. Res. 18:873-885. 1957.
508. Lovely, W.G. Experimental plot application equipment. Proc. Thirteenth Ann. Meet. North Central Branch Entomological Soc. Amer. 13:77-78. 1958.
_____, joint author. See under Fairchild, Kwolek, Weber.
Lowrie, J.A., joint author. See under Palmer.
509. Lowry, R.A. and G.H. Miller. Ionization yield of protons in nitrogen and argon. Phys. Rev. 109:826-831. 1958.
510. Lu, L.W., D.T. Davidson, R.L. Handy and J.G. Laguros. The calcium-magnesium ratio in soil-lime stabilization. Highway Res. Board Proc. (NAS-NRC Publication 542). 36:794-805. 1957.
Luke, H.H., joint author. See under Simons.
511. Lunden, Walter A. The mobility of state prison wardens. Police pp. 24-25. May-June, 1958.
512. Lundvall, R. L. Tibial injuries and recurrent patellar luxations in young horses. Iowa State Coll. Vet. 2:101-103. 1957.
513. _____. Chlorpromazine hydrochloride for tetanus in the horse. Jour. Amer. Vet. Med. Assoc. 132:254-255. 1958.
514. _____ and Richard C. Campbell. Chlorpromazine hydrochloride for the examination of the penis in bulls. Jour. Amer. Vet. Med. Assoc. 131:86-87. 1957.
515. Lusas, Edmund. White metal fittings may be the cause of oxidized flavor development in milk. Amer. Milk Rev. 19(7):96-99. 1957.
Lush, J.L., joint author. See under Anderson, D.E., Meadows, Von Krosigk.
Lutjens, D., joint author. See under Fox.

516. Maasland, Marinus. Soil anisotropy and land drainage. in: Drainage of Agricultural Lands. Ed. 1. pp. 216-285. Agronomy (Monograph series, vol. 7). 1957.
Mackie, A., joint author. See under Heady.
517. MacKinney, Arthur C. Levels in the evaluation of training. Personnel. pp. 72-77. Nov./Dec., 1957.
518. _____. A validation of tachistoscopic training for clerical workers. Personnel Psych. 11(1):13-23. 1958.
Maher, H., joint author. See under Freeman.
519. Mahlstede, J.P. Modern nursery packaging. Flower and Garden's Merchandiser. 1(9):6-21. 1957.
520. _____. Marketing of bare-root rose plants. American Nurseyman. 107(10):9-80. 1958.
521. _____. Evaluation of the rooting response of cuttings by the method of ranks. Proc. Amer. Soc. Hort. Sci. 71:585-590. 1958.
_____, Editor. Proceedings of the Plant Propagators Society.
522. Maier, George D. and David E. Metzler. Structures of thiamine in basic solutions. Jour. Amer. Chem. Soc. 79:4386-4391. 1957.
523. Maki, W.R. Economic effects of short-run changes in demand for livestock and meats. Jour. Farm Econ. 39:1670-1674. 1957.

Malone, C.A., joint author. See under Ogg.

524. Malone, C.C. The need for agricultural adjustment. Iowa State College Spec. Rept. No. 21. in: A Basebook for Agricultural Adjustment in Iowa. Part II. pp. 5-9. 1957.

525. _____ and L. H. Malone. Decision making and management for farm and home. Ed. 1. 260 pp. Iowa State College Press. 1958.

_____, joint author. See under Rosenfeld.

Malone, L.H., joint author. See under Malone, C.C.

Mangotich, E., joint author. See under Livingston.

Manthos, E.J., joint author. See under Rogers.

526. Marcus, R. and C.P. Wilsie. Inheritance of exposed stigma mutant in alfalfa. Agron. Jour. 49:604-606. 1957.

Martin, D.S., Jr., joint author. See under Elleman, Henry, Schupp.

527. Marvin, K.R. Technical writing and editing. Quill and Scroll. 32(4):12-25. 1958.

Mason, R.B., joint author. See under Melampy.

528. Mathews, John and D.A. Buthala. Toxicity of heated swine serum. Amer. Jour. Vet. Res. 19(70):32-36. 1958.

529. Mayo, Frank R., A.A. Miller and Glen A. Russell. The oxidation of unsaturated compounds. IX. The effects of structure on the rates and products of oxidation of unsaturated compounds. Jour. Amer. Chem. Soc. 80:2500-2507. 1958.

530. McComb, A.L. and G.W. Thomson. Growth of oaks in southeastern Iowa in relation to stand density and grazing. Proc. Iowa Acad. Sci. 64:93-103. 1957.

_____, joint author. See under Hansen.

McGee, H.A., Jr., joint author. See under Hirschfelder.

531. McKinley, Marjorie M. Simplify work in your church kitchen. Iowa Farm Science. 12(6):11-14. 1957.

_____, Abstractor, Institution Administration Section. Jour. Home Economics.

532. McKinney, L.L., F.B. Weakley, R.E. Campbell, A.C. Eldridge, J.C. Cowan, J.C. Picken, Jr. and N.L. Jacobson. Toxic protein from trichloroethylene-extracted soybean oil meal. Jour. Amer. Oil Chem. Soc. 34:461-466. 1957.

533. McNabb, Harold S., Jr. and Malcolm C. Shurtleff, Jr. Notes on stem rusts of hard pines in Iowa. Proc. Iowa Acad. Sci. 64:187-188. 1957.

_____, joint author. See under Fritch.

534. Meadows, Clinton E. and Jay L. Lush. Twinning in dairy cattle and its relation to production. Jour. Dairy Sci. 40:1430-1436. 1957.

535. Meen, R.H. and H. Gilman. Tetrasubstituted higher aliphatic and phenyl silanes. Jour. Organic Chem. 23:314-316. 1958.

536. Meier, Gerald G. Further study on comparison of the Ream Motility Test with the Rotary Activity Test. Proc. Iowa Acad. Sci. 64:553-556. 1957.

537. Meinwald, J. and O.L. Chapman. γ - Tropolone from some suitably substituted tropanes. Jour. Amer. Chem. Soc. 80:633-636. 1958.

_____, joint author. See under Chapman.

538. Melampy, R.M., M.A. Emmerson, J.M. Rakes, L.J. Hanka and P.G. Eness. The effect of progesterone on the estrous response of estrogen-conditioned ovariectonized cows. Jour. Animal Sci. 16:967-975. 1957.

539. _____ and R.B. Mason. Androgen and the myo-inositol content of male accessory organs of the rat. Proc. Soc. Expt. Biol. and Med. 96:405-408. 1957.

_____, joint author. See under Day, Rakes.

Mendell, F.H., joint author. See under Hendrickson.

540. Metcalfe, Darrel S. The agronomic education division - past, present and future. Agron. Jour. 49:647-650. 1957.

_____, joint author. See under Hughes.

Metzler, D.E., joint author. See under Maier.

541. Meyer, Fred P. The early bird gets the worm. Iowa Conservationist. 18:39. 1958.
542. Mickelson, R. and D. Peterson. Solubility of carbon in thorium. Trans. Amer. Soc. for Metals. 50:340-347. 1958.
Miles, D.H., joint author. See under Gilman.
Miller, A.A., joint author. See under Mayo.
Miller, G.H., joint author. See under Lowry.
Miller, R.E., joint author. See under Gerstein.
Mills, F.E., joint author. See under Kerst.
Minturn, R.E., joint author. See under Hansen, R.S.
543. Moldenhauer, W.C., J.R. Cover and M.E. Everhart. Control of wind erosion in the sandy lands of the southern high plains of Texas and New Mexico. U.S.D.A. ARS 41-20. 13 pp. 1958.
544. _____ and F. E. Keating. Relationships between climatic factors and yields of cotton, Milo and Kafir on sandy soils in the southern high plains. U.S.D.A. Prod. Res. Report No. 19. 13 pp. 1958.
_____, joint author. See under Burnett, Coover.
Moore, L.O., joint author. See under Gilman.
545. Moorman, Robert B. Some factors related to success of fish populations in Iowa Farm Ponds. Trans. Amer. Fisheries Soc. 86:361-370. 1957.
546. _____. Reproduction and growth of fishes in Marion County, Iowa farm ponds. Iowa State Coll. Jour. Sci. 32:71-88. 1957.
547. Morgan, P.E. and E. Robert Baumann. Trickling filters successfully treat milk wastes. Jour. Am. Soc. Civil Eng., Sanitary Eng. Div. Paper No. 1336. pp. 1-34. Aug., 1957.
Moren, R.I., joint author. See under Freeman.
548. Morin, Robert E. (Book review) Elementary Statistics, by Henry E. Garrett. Longmans, Green and Co., 1956. Psychometrika. 23:182-183. 1958.
549. _____. (Book review) Basic Statistical Concepts, by Joe K. Adams. McGraw-Hill Book Co., 1955. Psychometrika. 23:180-182. 1958.
550. Morris, R.G., R.D. Redin and G.C. Danielson. Semiconducting properties of Mg_2Si single crystals. Phys. Rev. 109:1909-1915. 1958.
_____, joint author. See under Redin.
551. Moser, H.C. and A.F. Voigt. The extraction of mercury(II) iodide. Nuclear Chem. 4:354-357. 1957.
Moskowitz, S., joint author. See under Bray.
Moss, L.C., joint author. See under Booth.
Moye, A.J., joint author. See under Fritz.
552. Muncy, R. Jess. Movements of channel catfish in Des Moines River, Boone County, Iowa. Iowa State Coll. Jour. Sci. 32:563-571. 1958.
553. _____. Trammel net increases sampling efficiency of the electric shocker. Progressive Fish-Culturist. 20:88. 1958.
554. Murphy, Glenn. Properties of engineering materials. Ed. 3. 464 pp. International Textbook Co. 1957.
555. _____. Recent advances in the engineering sciences - solid state physics and engineering materials. pp. 223-229. McGraw-Hill, New York. 1958.
Murphy, H.C., joint author. See under Simons.

Nakayama, F.S., joint author. See under Runkles.
556. Neagle, Lyle H., Paul A. Hartman and Damon C. Catron. Bacterial and fungal enzymes in baby pig diets. Bact. Proc. 1958:16. 1958.
Nelson, F.E., joint author. See under Baughman.
557. Nicholls, R.L. and D.T. Davidson. Soil stabilization with large organic cations and polyacids. Proc. Iowa Acad. Sci. 64:349-381. 1957.
Nicholson, R.P., joint author. See under Prill.
558. Nielsen, Duane M. Relationship of high school vocational agriculture and size of home farm to establishment of graduates in farming. Dissertation Abstracts. University Microfilms, Inc., Ann Arbor, Mich.

Nielson, D.R., joint author. See under Adams, Fuller.
Nixon, P.R., joint author. See under Schwab.
559. Nordin, Philip and Dexter French. 1-phenyl-flavazole derivatives of starch dextrins. Jour. Amer. Chem. Soc. 80:1445-1447. 1958.

560. O'Byrne, J.C. and J.F. Timmons. About Iowa's new water law. Iowa Farm Science. 12(6):7-10. 1957.
561. Oest, Irwin W. Iowa - state of opportunity? Iowa Farm Science. 13(1):3-4. 1958.
562. _____. Iowa opportunity - where does industry locate? Iowa Farm Science. 13(3):5-8. 1958.
563. _____. Iowa opportunity - is industry an answer? Iowa Farm Science. 13(2):5-7. 1958.
Ogilvie, J.C., joint author. See under Sheeler.
564. Ogg, Wallace E. Do or can current farm programs contribute to agricultural adjustment? Iowa State College Spec. Rept. No. 22. in: A Basebook for Agricultural Adjustment in Iowa. Part III. pp. 9-13. 1957.
565. _____ and C.A. Malone. A through G. Our changing agriculture. Agric. and Home Econ. Ext. Bull. Pm-245. 6 pp. Dec., 1957.
Ohkawa, T., joint author. See under Kerst.
O'Laughlin, J.W., joint author. See under Banks.
Oliver, R.T., joint author. See under Fritz.
566. Orgell, Wallace H. Sorptive properties of plant cuticle. Proc. Iowa Acad. Sci. 64:189-198. 1957.
567. _____. Problems associated with systemic action in plants. Proc., 12th. Ann. Meet. North Central Branch, Entomol. Soc. Amer. 12:63. 1957.
568. _____ and R.L. Weintraub. Influence of some ions on foliar absorption of 2,4-D. Botanical Gazette. 119:88-93. 1957.
Orillo, F.T., joint author. See under Reddy.
569. O'Sullivan, J.B. and Keith M. Hussey. Problems associated with soils stabilization in the vicinity of Pt. Barrow, Alaska. Proc. Iowa Acad. Sci. 64:429-442. 1957.
570. Ott, J.L. and C.H. Werkman. Coupled nucleoside phorphorylase reactions in Escherichia coli. Arch. Biochem. and Biophys. 69:264-276. 1957.
571. Owen, F.G., N.L. Jacobson, R.S. Allen and P.O. Homeyer. Nutritional factors in calf diarrhea. Jour. Dairy Sci. 41:662-670. 1958.
572. Owens, W.A., C.F. Schumacher and J.B. Clark. The measurement of creativity in machine design. Jour. Appl. Psych. 41:297-302. 1957.

573. Palmer, Raymond C., James A. Lowrie and John F. Speer. Writing from Experience. Ed. 1. 535 pp. Iowa State College Press. 1957.
574. Paloumpis, Andreas A. Responses of some minnows to flood and drought conditions in an intermittent stream. Iowa State Coll. Jour. Sci. 32: 547-561. 1958.
575. Pant, Chandra P. and Paul A. Dahm. An exploration of malathion as a protectant of stored corn. Proc., 12th. Ann. Meet., North Central Branch, Entomol. Soc. Amer. 12:36. 1957.
_____, joint author. See under Lindquist.
576. Parker, D.T., W.E. Larson and W.V. Bartholomew. Studies on nitrogen tie-up as influenced by location of plant residues in soils. Soil Sci. Soc. Amer., Proc. 21:608-612. 1957.
577. Patten, Lawton M. and Milton L. Rogness. Fundamentals of architectural drawing. Section I. Ed. 1. 67 pp. Iowa State College Book Store. 1958.
579. Paulsen, A., E.O. Heady and R.V. Baumann. What can corn allotments and soil banks do? Iowa Farm Science. 12(2):582. 1957.
Pavelis, G.A., joint author. See under Timmons.

Payne, L.C., joint author. See under Hegland.

580. Peacock, H.A. and C.P. Wilsie. Selection for resistance to seed pod shattering in birdsfoot trefoil (Lotus coruniculatus L.). Agron. Jour. 49:429-431. 1957.

Pearson, E.S., joint author. See under Fieller.

581. Pearson, G.J., P.O. Davey and G.C. Danielson. Thermal conductivity of nickel and uranium. Proc. Iowa Acad. Sci. 64:461-465. 1957.

_____, joint author. See under Strittmater.

582. Pease, Damaris and Bruce D. Gardner. Research on the effects of non-continuous mothering. Child Development. 29:141-148. 1958.

_____, joint author. See under Gardner.

Pechin, W.H., joint author. See under Williams.

Pedersen, J.H., joint author. See under Hull.

583. Penny, L.H. Some genetic aspects of selection for European corn borer resistance. Proc., 13th. Ann. Meet., North Central Branch, Entomol. Soc. Amer. 13:53-54. 1958.

584. _____ and F.F. Dicke. A single gene-pair controlling segregation for European corn borer resistance. Agron. Jour. 49:193-196. 1957.

_____, joint author. See under Dicke.

585. Peo, E.R., Jr., G.C. Ashton, V.C. Speer and D.V. Catron. Protein and fat requirements of baby pigs. Jour. Animal Sci. 16:885-891. 1957.

586. _____, V.W. Hays, G.C. Ashton, V.C. Speer, C.H. Liu and D.V. Catron. Application of the protein depletion-repletion technique in baby pig feeding experiments. I. A comparison of levels and sources of protein for baby pigs. Jour. Nutrition. 62:465-474. 1957.

587. _____, _____, _____, _____, _____, _____. Application of the protein depletion-repletion technique in baby pig feeding experiments. II. Effect of levels of protein on repletion gains and blood serum components of baby pigs. Jour. Nutrition. 62:475-488. 1957.

Pesek, J., joint author. See under Gross, Webb, White.

Peterson, D., joint author. See under Mickelson.

Peterson, F.L., joint author. See under Kerst.

Peterson, L.E., joint author. See under Hibbs.

Peterson, N.C., joint author. See under Duke.

588. Peterson, Peter A. Cytoplasmically inherited male sterility in capsicum. The American Naturalist. 92(863):111-119. 1958.

589. Phillips, Richard. Agribusiness: Its implications for agricultural economics. Proc., Marketing Section, Assoc. Southern Agric. Workers. 10 pp. Feb., 1958.

590. _____. Grain marketing. in: The Midwest Farm Handbook. Ed. 4. pp. 346-348. Iowa State College Press. 1957.

591. _____. How will integration affect farm supply dealers? Farm Store Merchandising. 1(2):24-25. 1958.

592. _____. Managing for greater returns in country elevator and retail farm supply businesses. Ed. 1. 558 pp. Farmers Grain Dealers Assoc., Des Moines, Iowa. 1957.

593. _____. Other product lines for sales and profits. Hatchery and Feed. pp. 40-44. April, 1958.

594. _____. Training methods and procedures for developing management skills. in: American Cooperation. pp. 700-706. 1957.

595. _____. What about feeder contracts for dealers? Feedstuffs. pp. 72-73. May 24, 1958.

596. _____. Will integration revolutionize midwestern agriculture? Westernews. 19(8):12-16. 1958.

_____, joint author. See under Balloun.

Picken, J.C., Jr., joint author. See under McKinney.

597. Pierre, W.H. Relationship of soil classification to other branches of soil science. Soil Sci. Soc. Amer., Proc. 22:167-170. 1958.

598. _____ and F.F. Riecken. The midland feed region. in: Soil. The 1957 Yearbook of Agriculture. Ed. 1. pp. 535-546. U.S. Dept. Agric. 1957.

_____, Consulting Editor. Agronomy Journal.
_____, Consulting Editor. Soil Science.
Pietrzyk, D.J., joint author. See under Fritz.
599. Pinches, Robert R. and L.J. Bodensteiner. The role of education in promoting adjustment. Iowa State College Spec. Rept. No. 22. in: A Basebook for Agricultural Adjustment in Iowa. Part III. pp. 25-30. 1957.
600. Pirchner, F., R.S. Allen and N.L. Jacobson. Effect of diphenyl-p-phenylenediamine on the utilization of carotene and vitamin A by the calf. Jour. Dairy Sci. 15(11):1448-1456. 1957.
602. Pirko, Paul C. and John C. Ayres. Pigment changes in packaged beef during storage. Food Tech. 11:461-468. 1957.
Polder, E.R., joint author. See under Hendrickson.
Porter, A.R., joint author. See under Foreman.
Post, A.H., joint author. See under Larson.
Potgieter, F., joint author. See under Jebe.
603. Powell, J.E. and M.A. Hiller. Preparation of carbonate-free bases. Jour. Chem. Educ. 34:330. 1957.
604. Preston, Rodney L. and Wise Burroughs. Stilbestrol responses in lambs fed rations differing in calorie to protein ratios. Jour. Animal Sci. 17:140-151. 1958.
605. Prill, R.C. and F.F. Riecken. Variations in forest-derived soils formed from Kansan till in southern and southeastern Iowa. Soil Sci. Soc. Amer., Proc. 22:70-75. 1958.
606. _____, W.D. Shrader and R.P. Nicholson. Relationship of topography to the distribution of soils and to loess thickness on the Galva-Primghar Experimental Farm. Proc. Iowa Acad. Sci. 64:400-406. 1957.
_____, joint author. See under Simonson.
607. Pulsifer, H.G. Damping-off of cotton seedlings caused by Colletotrichum hibisci Poll. Iowa State Coll. Jour. Sci. 32:57-61. 1957.
Purchase, M.E., joint author. See under Hansen, R.S.

608. Quinn, Loyd Y. A culture apparatus suitable for performance of the presumptive test for the coliform group under field conditions. Iowa State Coll. Jour. Sci. 32:541-546. 1958.
609. _____, Vaughan C. Speer and D.V. Catron. Hemagglutinin titers in swine against an enteropathogenic strain of Escherichia coli. Bact. Proc. p. 26. 1957.
610. _____, R. D. Wilbur, H. Zucker, H. Brown and D.V. Catron. In vitro response of Candida albicans and Candida tropicalis to antifungal agents. Bact. Proc. pp. 21-22. 1957.

611. Rackham, Thomas S. Beef-exodus-fortune or misfortune. Canadian Cattlemen. March, 1958. Calgary, Alberta, Canada.
612. _____. It's your business. II. Milk producers' alternatives in western Montana. Agric. Econ. Res. Rept. No. 4. 11 pp. 1957.
613. _____. It's your business. I. Cream producers' alternatives in western Montana. Montana Agric. Expt. Sta. Agric. Econ. Res. Rept. No. 3. 11 pp. 1957.
614. _____. Cattle and corn. Canadian Cattlemen. April, 1958. Calgary, Alberta, Canada.
615. _____. Farm outlook. Iowa Farm Science. June, 1958.
616. _____. Range beyond the hill. Canadian Cattlemen. Sept., 1957. Calgary, Alberta, Canada.
_____, joint author. See under Kutish.
617. Rakes, J.M., J.W. Gurland and R.M. Melampy. Estrogen excretion by cows. (Abstract) Jour. Animal Sci. 16:1105. 1957.

618. _____, L.J. Hanka and R.M. Melampy. Estrous behavior in spayed cows receiving estradial benzoate and progesterone. (Abstract) Jour. Animal Sci. 16:1096. 1957.

_____, joint author. See under Melampy.

619. Ramsey, F.K., W.H. Chivers, A.L. Trapp and C.E. Whiteman. Incidence and mortality of mucosal disease in Iowa. Iowa State Coll. Veterinarian. 20(2):101-103. 1958.

_____, joint author. See under Trapp.

Ranck, R.O., joint author. See under Gilman.

Rao, R.K., joint author. See under Arnold.

620. Raun, E.S. Recent progress in control of livestock pests with systemic insecticides. Proc., 13th. Ann. Meet., North Central Branch, Entomol. Soc. Amer. 13:49-50. 1958.

621. _____. Controlling insect pests of cattle. Agric. and Home Econ. Ext. Bull. Pm-181. 2 pp. 1957.

622. _____ and John B. Herrick. Systemic insecticides control cattle grubs. Iowa Farm Science. 13(2):3-4. 1958.

623. _____, _____. Feedlot tests of the efficacy of Dow ET-57 (Trolene) for control of cattle grubs. Jour. Amer. Vet. Med. Assoc. 131:421-423. 1957.

624. _____, _____. Clinical test of the efficacy of Dow ET-57 for grub control in cattle. Jour. Econ. Entomol. 50:832. 1957.

_____, joint author. See under Gless.

625. Ray, A.E. and J.F. Smith. A method for growing small spherical crystals of metals and alloys. Acta Crystallographica. 11:310. 1958.

626. _____, _____. Composition variation in the α-phase compound of the vanadium-aluminum system. Acta. Crystallographica. 10:604-605. 1957.

627. Reddy, C.S., F.T. Orillo and L.N. Gibe. Spraying to control late blight of potatoes in the Philippines. Plant Dis. Reptr. 42:334-336. 1958.

628. Redin, R.D. and G.C. Danielson. Measurement of magnetic field gradients by the Hall effect. Iowa State Coll. Jour. Sci. 32:463-469. 1958.

629. _____, R.G. Morris and G.C. Danielson. Semiconducting properties of Mg_2Ge single crystals. Phys. Rev. 109:1916-1920. 1958.

_____, joint author. See under Morris.

Reishus, J.W., joint author. See under Elleman.

630. Rhodes, B.L., S. Legvold and F.H. Spedding. Magnetic properties of holmium and thulium metals. Phys. Rev. 109:1547-1550. 1958.

Rice, M.H., joint author. See under Barlett.

Richard, M.J., joint author. See under Fritz.

631. Richardson, A.E. and A.F. Voigt. Chemical effects of photonuclear reactions in the propyl bromides. Jour. Chem. Phys. 28:854-863. 1958.

632. Ridenhour, Richard L. Northern pike, Esox lucius L., population of Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 32:1-18. 1957.

_____, joint author. See under DiCostanzo.

Riecken, F.F., joint author. See under Pierre, Prill, Shrader, Simonson.

Robb, E.W., joint author. See under Wenkert.

Roberson, O., joint author. See under Jebe.

633. Robertson, Fred. Mathematics training for the exceptional student. Proc. Iowa Acad. Sci. 64:448-452. 1957.

Robinson, J.L., joint author. See under Hutchcroft.

634. Robotka, Frank. Vom nutzen der genossenschaftstheorie. Zeitschrift für das Gasamte Genossenschaftswesen. 8:70-82. 1958.

635. Rogers, B.A. The properties of eleven less common metals. in: Metals for Supersonic Aircraft and Missiles. by: D.W. Grobecker. pp. 261-314. American Socity for Metals, Cleveland. 1958.

636. _____, D.F. Atkins, E.J. Manthos and M.E. Kirkpatrick. Uranium-columbium alloy diagram. Trans. Metallurgical Soc. Amer. Inst. of Mining, Metallurgical and Petroleum Engrs. 212:387-393. 1958.

637. Rogers, Everett M. A conceptual variable analysis of technological change. Rural Sociology. 23:136-145. 1958.

638. ____ and George M. Beal. The importance of personal influence in the adoption of technological changes. Social Forces. 36(4):329-335. 1958.

639. _____, _____. Reference group influence in the adoption of agricultural technology. Ed. 1. 83 pp. Economics and Sociology Dept., Iowa State College. 1958.

_____, joint author. See under Beal.

Rogness, M.L., joint author. See under Patten.

640. Rojas, B. and R.F. White. The modified latin square. Jour. Royal Stat. Soc. Series B (Methodological). 19:305-317. 1957.

641. Ronwin, E. N-acylated amino acid imino chlorides and a qualitative study of ring closure among N-acylamine acid chlorides. Canadian Jour. Chem. 35:1031-1038. 1957.

642. _____. Optical activity and the direct method of acylation. Jour. Organic Chem. 22:1180-1182. 1957.

643. Rosenfeld, Louise and Carl Malone. Today's farm woman in the changing farm scene. The Business of Farming. pp. 9-11. Jan-Feb., 1958.

644. Rothenbuhler, Walter C. Genetics and breeding of the honey bee. Ann. Rev. of Entomol. 3:161-180. 1958.

645. _____. Diploid male tissue as new evidence on sex determination in honey bees. Jour. Heredity. 48:160-168. 1957.

_____, Science Editor. American Bee Journal.

_____, joint author. See under Thompson.

Roychaudhuri, D.K., joint author. See under Wenkert.

Royer, Keith, Editor. Fire Service Information Bulletin.

646. Ruan, E. and K.J. Frey. Effect of heat treatment on oat seeds. Proc. Iowa Acad. Sci. 64:139-148. 1957.

_____, joint author. See under Frey.

Rubin, M., joint author. See under Ruhe.

Ruchte, M.F., joint author. See under Herstein.

647. Ruhe, R.V. and R.B. Daniels. Soils, paleosols, and soil horizon nomenclature. Soil Sci. Soc. Amer., Proc. 22:66-69. 1958.

648. _____, M. Rubin and W.H. Scholtes. Late pleistocene radiocarbon chronology in Iowa. Amer. Jour. Sci. 255:671-689. 1957.

649. Rundle, R.E. Antiferromagnetic ordering and electronic structure of $CuCl_2 \cdot 2H_2O$ as determined from nuclear magnetic resonance. Jour. Amer. Chem. Soc. 79:3372-3374. 1957.

_____, joint author. See under Atoji, Dahl, L.F., Smith, H.G.

650. Runkles, J.R., A.D. Scott and F.S. Nakayama. Oxygen sorption by moist soils and vermiculite. Soil Sci. Soc. Amer., Proc. 22:15-18. 1958.

_____, joint author. See under Shaw, R.H.

651. Russell, Glen A. Solvent effects in the reactions of free radicals and atoms. Jour. Amer. Chem. Soc. 79:2977. 1957.

652. _____. Deuterium-isotope effects in the autoxidation of aralkyl hydrocarbons. Mechanism of the interaction of peroxy radicals. Jour. Amer. Chem. Soc. 79:3871-3877. 1957.

_____, joint author. See under Mayo.

Russell, W.A., joint author. See under Sprague.

653. Sadanage, Kiyoshi. Cytological studies of hybrids involving triticum durum and secale cereals. I. Alien addition races in tetraploid wheat. Cytologia 22(3-4):312-321. 1957.

654. Samuelson, J.M. and G.O. Hendrickson. Water-bird migration at Goose and Little Wall Lakes, Hamilton County, Iowa, spring of 1955. Iowa Bird Life. 28:20-21. 1958.

655. Sanderson, D.E. Isotopy in 3-manifolds. I. Isotopic deformations of 2-cells and 3-cells. Proc. Amer. Math. Soc. 8:912-922. 1957.
656. Santucci, L. and H. Gilman. Some bromine-containing and sulfur-containing aromatic boronic acids. Jour. Amer. Chem. Soc. 80:193-196. 1958.
657. Sass, John E. Histolytic polyploidy in root tips of maize. Proc. Iowa Acad. Sci. 64:213-217. 1957.
658. _____. Botanical Microtechnique. Ed. 3. 228 pp. Iowa State College Press. 1957.
Schaeffer, R., joint author. See under Tallon.
659. Schaller, F.W., Paul Jacobson and D.O. Hull. Grassed waterways and terrace outlets. Agric. and Home Econ. Ext. Serv. Bull. No. Pm-166. 1957.
_____, joint author. See under Larson.
660. Schlebecker, John T. An informal history of hitchhiking. The Historian. 20:305-327. 1958.
661. _____. Dairy journalism: Studies in successful farm journalism. Agric. Hist. 31:23-33. 1957.
662. _____. Pliant prairie: One plant's influence on one state. Montana, the Magazine of Western History. 8:30-41. 1958.
663. _____ and Andrew W. Hopkins. A history of dairy journalism in the United States, 1810-1950. Ed. 1. 416 pp. University of Wisconsin Press. 1957.
664. Schmidt, J.L. How does your corn dry? Iowa Farm Science. 12(4):6-8. 1957.
665. Schnittker, John and Earl O. Heady. Application of input-output analysis to a regional model emphasizing agriculture. Iowa Agric. Expt. Sta. Bull. No. 454. 20 pp. 1957.
_____, joint author. See under Heady.
666. Scholl, J.M., R.R. Kalton and H.E. Thompson. Orchardgrass - its use on Iowa farms. Iowa Farm Science. 12(9):7-8. 1958.
667. _____ and D.W. Staniforth. Birdsfoot trefoil establishment. Down to Earth. pp. 7-8. 1958.
668. _____, _____. Establishment of birdsfoot trefoil as influenced by competition from weeds and companion crops. Agron. Jour. 49:432-435. 1957.
_____, joint author. See under Staniforth.
669. Scholtes, W.H. Preparation and use of 3-dimension projections in teaching soil classification. Soil Sci. Soc. Amer., Proc. 21:442-444. 1957.
_____, joint author. See under Adams, Ruhe.
670. Schroeder, Ira. Listener's handbook - a guide to music appreciation. Ed. 1. 173 pp. Wm. C. Brown Gook Co., Dubuque, Iowa. 1958.
671. _____. The Stanton Memorial Carillon - a history of the Edgar W. and Margaret MacDonald Stanton Memorial Carillon. Bull. of the Guild of Carillonneurs in North America. 10(1):1-10. 1957.
Schumacher, C.F., joint author. See under Owens.
672. Schupp, F.D., C.B. Colvin and D.S. Martin, Jr. Cross section for the Ca^{40} (γ,3p3n) Cl^{34} reaction. Phys. Rev. 107:1058-1061. 1957.
673. Schwab, G.O., Don Kirkham and H.P. Johnson. Effect of tile spacing on crop yield and water table level in a planosol soil. Soil Sci. Soc. Amer., Proc. 21:448-452. 1957.
674. _____, W.D. Shrader, P.R. Nixon and R.H. Shaw. Research on corn and soybeans at Conesville and Ankeny, Iowa, 1951 to 1955. Iowa State College Res. Bull. No. 458. 12 pp. 1958.
675. Schwarte, L.H. Experimental investigations on current strains of hog cholera virus. Jour. Amer. Vet. Med. Assoc. 131(2):93-94. 1957.
Schwarte, M.K., joint author. See under Fritch.
676. Schwenk, L.C. Analysis of the 1956 automobile fatalities in Iowa by age, sex and other factors. Proc. Iowa Acad. Sci. 64:541. 1957.
678. Scott, A.D., J.L. Ahlrichs and G. Stanford. Aluminum effect on potassium fixation by Wyoming bentonite. Soil Science. 84:377-387. 1957.
679. _____, J.J. Hanway and E.M. Stickney. Soil potassium - moisture relations. I. Potassium release observed on drying Iowa soils with added salts or HCl. Soil Sci. Soc. Amer., Proc. 21:498-501. 1957.

_____, joint author. See under Hanway, Runkles.
Seabaugh, P.W., joint author. See under Corbett.
680. Seaton, V.A. Pulmonary adenomatosis in Iowa cattle. Amer. Jour. Vet. Res. 19:600-609. 1958.
Seay, W.A., joint author. See under Sutton.
681. Segel, S.L. and R.G. Barnes. Nuclear quadrupole moment ratio of Re^{185} and Re^{187}. Phys. Rev. 107:638. 1957.
_____, joint author. See under Bray.
682. Seidel, H.F. and E. Robert Baumann. A statistical analysis of water works operating data for 1955. Jour. Amer. Water Works Assoc. 49:1531-1566. 1957.
683. Seifert, George. On stability in the large for periodic solutions of differential systems. Annals of Mathematics. 67:83-89. 1958.
Seral, W., joint author. See under Fox, S.W.
Serovy, G.K., joint author. See under Budinger, Costello.
Sessler, A.M., joint author. See under Kerst, Laslett.
684. Sharp, E.L. and F.G. Smith. Further of the preservation of *Puccinia* uredospores. Phytopath. 47:423-429. 1957.
685. Shaw, R.H. and W. F. Buchele. The effect of the shape of the soil surface profile on soil temperature and moisture. Iowa State Coll. Jour. Sci. 32:95-104. 1957.
686. _____ and C.C. Doll. Variation in minimum temperatures on a half mile slope and their effect on peach trees. Iowa State Coll. Jour. Sci. 32:63-69. 1957.
687. _____ and E.R. Duncan. Crop prospects for 1958. Iowa Farm Science. 12(7): 19-20. 1958.
688. _____ and C.R. Elford. What is weather? Iowa Farm Science. 12(8):5-6. 1958.
689. _____, _____. The air we live in. Iowa Farm Science. 12(10):6-8. 1958.
690. _____, _____. How you and I record the weather. Iowa Farm Science. 12(1): 13-16. 1958.
691. _____, _____. Clouds - the signposts of the sky. Iowa Farm Science. 12(12):3-6. 1958.
692. _____, _____. Why our weather changes. Iowa Farm Science. 12(13):5-8. 1958.
693. _____, J.R. Runkles and G.L. Barger. Seasonal changes in soil moisture as related to rainfall, soil type and crop growth. Iowa State Coll. Res. Bull. No. 457. 1958.
694. _____ and Yi-Ming Yao. Estimation of evaporation from farm ponds. Iowa State Coll. Jour. Sci. 32:349-353. 1958.
_____, joint author. See under Schwab.
695. Shaw, W.C., D.E. Husdon and G.C. Danielson. Electrical properties of boron single crystals. Phys. Rev. 107:419-427. 1957.
696. Sheeler, J.B. and D.T. Davidson. Further correlation of consistency limits of Iowa loess with clay content. Proc. Iowa Acad. Sci. 64:407-412. 1957.
697. _____, J.C. Ogilvie and D.T. Davidson. Stabilization of loess with aniline-furfural. Highway Res. Brd. Proc. (NAS-NRC Publ. 542). 36:755-772. 1957.
698. Shepherd, G.S. Have agricultural programs contributed to long-run agricultural adjustments? Iowa State Coll. Spec. Rept. No. 22. in: A Basebook for Agricultural Adjustment in Iowa. pp. 5-8. 1957.
699. _____, R.R. Beneke and W.A. Fuller. Alternative parity formulas. in: Policy for Commercial Agriculture. Its Relation to Economic Growth and Stability. pp. 526-533. Joint Economic Committee. 1957.
Shoemaker, H.E., joint author. See under Chiotte.
700. Shrader, W.D. and F.F. Riecken. Adjustments in the cropping pattern of Iowa agriculture. Iowa State Coll. Spec. Rept. No. 21. in: A Basebook for Agricultural Adjustment in Iowa. pp. 26-30. Iowa State College Press. 1957.

_____, joint author. See under Bartholomew, Prill, Schwab.

701. Shurtleff, Malcolm C. 1958 plant disease chemicals. Iowa State Coll. Bull. PD-36 (revised). 1958.

702. _____. Lawn diseases. Iowa State Coll. Bull. Pd-37. 1958.

703. _____. Plant disease outlook for 1958. Iowa Farm Science. 12:686. 1958.

704. _____, H.D. Wells and T.E. Freeman. Declare war on turf disease. Parks and Recreation Magazine. 41(5):230-232. 1958.

_____, joint author. See under Cott.

Shurtleff, M.C., Jr., joint author. See under McNabb.

705. Simons, M.D. Physiologic races of crown rust of oats identified in 1956-57. Plant Disease Reporter. 41:970-972. 1957.

706. _____, H.H. Luke, W.H. Chapman, H.C. Murphy, A.T. Wallace and K.J. Frey. Further observations on races of crown rust attacking the oat varieties Landhafer and Santa Fe. Plant Disease Reporter. 41:964-969. 1957.

_____, Editor. Phytopathology.

707. Simonson, G.H., R.C. Prill and F.F. Riecken. Free iron distribution in some poorly drained prairie soils in Iowa. Proc. Iowa Acad. Sci. 64: 385-392. 1957.

708. Sinha, S.P., D.T. Davidson and J.M. Hoover. Lignins as stabilizing agents for northeastern Iowa loess. Proc. Iowa Acad. Sci. 64:314-348. 1957.

Skochdopole, R.E., joint author. See under Gerstein.

Skrdla, W.H., joint author. See under Blaser.

Sloss, M.W., joint author. See under Trapp.

709. Smith, Elbert B. Now defend yourself, you damned rascal! American Heritage. 9:44-47,106. 1958.

710. _____. Magnificent Missourian. Ed. 1. 351 pp. J.B. Lippincott Co., Philadelphia. 1958.

711. Smith, F.G. Germination and seed testing - a biochemical view. Golden Jubilee Publ., Assoc. of Official Seed Analysts. pp. 98-101. 1958.

_____, Assoc. Section Editor. Biological Abstracts.

_____, joint author. See under Sharp, Switzer.

712. Smith, H.G. and R.E. Rundle. X-ray investigation of perfection in tin whiskers. Jour. Appl. Phys. 29:679-683. 1958.

713. Smith, J.F., C.E. Carlson and F.H. Spedding. Elastic properties of yttrium and eleven of the rare earth elements. Jour. Metals. 9:1212-1213. 1957.

_____, joint author. See under Griffel, Ray, Vest.

714. Smith, Leslie. Your questions on food. Iowa Farm Science. 12(2):12-14. 1957.

715. Smith, Shirley-Jean. Your shoes and you. Iowa State Coll. Res. Bull. 4 pp. 1958.

716. _____. Look your best - a better groomed girl. Iowa State Coll. Res. Bull. HE-39. 4 pp. 1958.

Smith, W.G., joint author. See under Heady.

Smutz, M., joint author. See under Bochinski.

Snedecor, George W., Member of Editorial Board and editor of Queries Section. Biometrics.

Snowden, D.D., joint author. See under Bolton.

Snyder, J.N., joint author. See under Kerst, Laslett.

Soddy, T., joint author. See under Gilman.

Speake, D.W., joint author. See under Haugen.

Speaker, E.B., joint author. See under Hendrickson.

717. Spedding, F.H. The rare earths. in: The New Chemistry. pp. 89-101. Simon and Schuster, New York. 1958.

718. _____. Atomic fuels. Metal Progress. 72(4):105-111. 1957.

719. _____. Atomic fuels. in: Transactions Fifth World Power Conference, Vienna, 1956. 14:4969-4977. 1957. Austrian National Committee for World Power Conference, Vienna.

720. _____, R.J. Barton and A.H. Daane. The vapor pressure of thulium metal. Jour. Amer. Chem. Soc. 79:5160-5163. 1957.
721. _____, A.H. Daane and K.W. Herrmann. Electrical resistivites and phase transformations of lanthanum, cerium, praseodymium, and neodymium. Jour. Metals. 9:895-897. 1957.
722. _____, J.J. Hanak and A.H. Daane. The preparation and properties of europium. Trans. Metallurgical Soc. Amer. Inst. of Mining, Metallurgical and Petroleum Engrs. 212:379-383. 1958.
_____, joint author. See under Anderson, G.S., Atoji, Behrendt, Bochinski, Gerstein, Jennings, Rhodes, Smith, J.F.
723. Speer, V.C., H. Brown, L.Y. Quinn and D.V. Catron. Antibody absorption in the baby pig. Jour. Animal Sci., Proc., Amer. Soc. Animal Production. 16:1046-1047. 1957.
724. _____, E.L. Lasley, G.C. Ashton, L.N. Hazel and D.V. Catron. Protein levels for growing boars on pasture and concrete. Jour. Animal Sci. 16:607-611. 1957.
_____, joint author. See under Hays, Johnson, C.W., Palmer, Peo, Quinn, Zucker.
Spooner, J.L., joint author. See under Banks.
725. Sprague, G.F. and W.A. Russell. Some evidence on the type of gene action involved in yield heterosis in maize. Suppl. Vol. of Cytologia., Proc. Internatl. Genetics Symposia, 1956. pp. 522-526. 1957.
_____, Assoc. Statistics. Agronomy Journal.
726. Stacy, W.H. Spotlighting church-community programs. Iowa Farm Science. 12:723-724. 1958.
727. _____. Are community efforts meeting needs? Iowa Farm Science. 12(6):19-21. 1957.
Stadler, J., joint author. See under Gowen.
Staley, H.G., joint author. See under Svec.
Stanford, G., joint author. See under Scott.
728. Staniforth, David W. Weed control in soybeans and corn. Proc. 11th Meet. Eastern Sect., Natl. Weed Committee of Canada. pp. 1-4. 1958.
729. _____. Soybean-foxtail competition under varying soil moisture conditions. 50:13-15. 1958.
730. _____. Effects of annual grass weeds on the yield of corn. Agron. Jour. 49:551-555. 1957.
731. _____ and J.M. Scholl. Herbicides for trefoil seedings? Iowa Farm Science. 12:3-5. 1958.
732. _____ and Charles R. Weber. Residual pre-emergence herbicides in soybean production in Iowa. Weeds. 6:115-125. 1958.
_____, joint author. See under Scholl, Weber.
Stanton, R.M., joint author. See under Jennings.
Stoneberg, E.G., joint author. See under Heady.
733. Story, C.D., W.H. Hale, E.W. Cheng and W. Burroughs. The effect of low levels of diethylstilbestrol and plant estrogens upon performance of fattening lambs. Proc. Iowa Acad. Sci. 64:259-266. 1957.
734. _____, P.G. Homeyer and W.H. Hale. The effect of diethylstilbestrol on the digestibility of dry matter and nitrogen and on nitrogen retention in lambs. Proc. Iowa Acad. Sci. 64:267-271. 1957.
Strand, N.V., joint author. See under Gaardner.
735. Strittmater, R.C., G.J. Pearson and G.C. Danielson. Measurements of specific heats by a pulse method. Proc. Iowa Acad. Sci. 64:466-470. 1957.
Stritzel, J.A., joint author. See under Heady.
736. Struve, W.M. and W.E. Loomis. Results of current railroad weed control research at Iowa State College. Proc. North Central Weed Control Conf. 14:15-16. 1957.
_____, joint author. See under Loomis, W.E.
Stukney, E.M., joint author. See under Scott.

737. Suhr, V.W. Comparison of laboratory and field studies in the estimation of driving speed. Proc. Iowa Acad. Sci. 64:546-552. 1957.
____, joint author. See under Lauer.
Sutton, J.R., joint author. See under Hirschfelder.
738. Sutton, Paul and W.A. Seay. Relationship between potassium removed by millet and red clover and the potassium extracted by 4 chemical methods from 6 Kentucky soils. Soil Sci. Soc. Amer., Proc. 22:110-115. 1958.
739. Suzuki, I. and C.H. Werkman. Chemoautotropic carbon dioxide fixation by extracts of Thiobacillus thiooxidans. I. Formation of oxalacetic acid. Archives of Biochem. and Biophys. 76:103-111. 1958.
740. ____, ____. Phosphoenolpyruvate carboxylase in extracts of Thiobacillus thiooxidans, a chemoautotropic bacterium. Archives of Biochem. and Biophys. 72:514-515. 1957.
741. ____, ____. Chemoautotropic fixation of carbon dioxide by Thiobacillus thiooxidans. Iowa State Coll. Jour. Sci. 32:475-483. 1958.
742. Svec, H.J. and C. Apel. Metal-water reactions. IV. Kinetics of the reaction between calcium and water vapor. Jour. Electrochem. Soc. 104:346-349. 1957.
743. ____ and D.S. Gibbs. Metal-water reactions. V. Kinetics of the reaction between magnesium and water vapor. Jour. Electrochem. Soc. 104:434-439. 1957.
744. ____ and H.G. Staley. Metal-water reactions. VI. Kinetics of the reactions of water vapor with strontium and barium. Jour. Electrochem. Soc. 105:121-125. 1958.
____, joint author. See under Flesch, Junk, Tallon.
745. Swanson, Clifford. Effect of the prevailing speed law type in the traffic fatality rate in the U.S. Proc. Iowa Acad. Sci. 64:536-540. 1957.
746. Swanson, Pearl P. The challenge for home economics research: collection of addresses. in: The Challenge for Home Economics. pp. 35-45. University of Illinois. 1957.
____, joint author. See under Willis.
____, Chairman, Manuscript Committee. Iowa State College Press.
Swayampati, D.R., joint author. See under Gilman.
Swenson, Clayton, A., Member, Board of Editors. Review of Scientific Instruments.
747. Swenson, Melvin J., D.H. Will, Paul S. Eskridge and N.H. Booth. A preliminary report on the effects of iron-dextran, injected intramuscularly, on the growth rate of newborn pigs. Jour. Amer. Vet. Med. Assoc. 131(3): 146-147. 1947.
748. ____, G.K.L. Underbjerg, E.E. Bartley and W.G. Jones. Effects of trace minerals, aureomycin, and other supplements on certain hematologic values and organ weights of dairy calves. Jour. Dairy Sci. 15(12): 1525-1533. 1957.
____, joint author. See under Booth.
____, Research Council, A.V.M.A. American Journal of Veterinary Research.
749. Switzer, Clayton M. and Frederick G. Smith. Factors affecting oxidation and phosphorylation by soybean mitochondria. Canadian Jour. Bot. 35: 515-525. 1957.
750. Sylvester, E.P. The impact of television on educational meetings. North Cent. Weed Control Conf. 14th Ann. Meet., Proc. pp.21-22. 1958.
751. ____. Profits from extension weed control. 16th Western Weed Control Conf., Proc. pp. 5-9. 1958.
752. ____. Noxious weeds. Iowa State Coll. Agric. Expt. Sta. Bull. 81-B. pp. 1-75. 1958.

Tabeling, R.W., joint author. See under Fassel.

753. Talbot, R.B. North Dakota Farmers Union and North Dakota politics. Western Political Science Quarterly. 10:875-901. 1957.
754. _____. North Dakota - a two party state? The North Dakota Quarterly. 25:93-104. 1957.
755. Taves, Marvin J. and R.R. Pinches. Community relations of rural adult youth. Minnesota Farm and Home Science. 16(1). 1958.
Taylor, T.H., joint author. See under Blaser.
756. Thoma, J.A. and Dexter French. Paper chromatography of homologous saccharides. Analyt. Chem. 29:1645-1648. 1957.
Thomas, L.A., joint author. See under Welp.
757. Thomas, W.I. and John C. Eldredge. Mmm - popcorn. Iowa Farm Science. 12:9-10. 1958.
_____, joint author. See under Whitely.
Thompson, H.E., joint author. See under Scholl.
Thompson, J.A., joint author. See under Banks.
758. Thompson, Victor C. and W.C. Rothnbuhler. Resistance to American foulbrood in honey beeds. II. Differential protection of larvae by adults of different genetic lines. Jour. Econ. Entomol. 50:731-737. 1957.
Thomson, G.W., joint author. See under McComb.
Tiffany, L.H., joint author. See under Gilman.
Tillman, A.D., joint author. See under Woods.
759. Timmons, John F. About Iowa's new water law. Iowa Farm Science. 12(6): 7-10. 1957.
760. _____. Theoretical considerations of water allocation among competing uses and users. Jour. Farm Econ. 38:1244-1258. 1956.
761. _____. Agriculture's capacity to adjust. Iowa State College Spec. Rept. No. 20. in: A Basebook for Agricultural Adjustment in Iowa. pp. 22-27. Iowa State College Press. 1957.
762. _____. Improving agricultural tenancies. in: United Nation's Food and Agricultural Technical Monograph No. 35. Ed. 1. 39 pp. 1957.
763. _____ and George A. Pavelis. Effects of federal agricultural spending. The Farm Policy Forum. 10(1):25-28. 1957.
_____, joint author. See under O'Byrne.
764. Tintner, Gerhard. Game theory, linear programming, and input-output analysis. Zeitschrift fuer Nationaloekonomie. 17:1-38. 1957.
765. _____. Mathematics and statistics for economists. Metroeconomica. 8: 146-148. 1957.
766. _____. Strategische spieltheorie und ihre anwendung in den sozialwissenschaften. Allgemeines Statistisches Archiv. Heft 3:242-251. 1957.
767. _____. Economics in the United States of America. (Book review) Zeitschrift für Nationalökonomie. 17:363. 1957.
768. _____. Produktionsfunktionen für die österreichische landwirtschaft. Zeitschrift für Nationalökonomie. 17:426-442. 1958.
769. _____. Angebots- und Nachfragefunktionen für einige Fleischsorten in Österreich. Zeitschrift für Nationalökonomie. 17:443-468. 1958.
770. _____. (Book review) The Lognormal Distribution, with Special Reference to Its Use in Economics. by: J. Aitchison and J.A.C. Brown. Cambridge University Press. 1957. Jour. Amer. Statistical Assoc. 53:219-220. 1958.
771. _____. (Book review) Economic Models - An Exposition. by: E.F. Beach. John Wiley and Sons. 1957. Amer. Econ. Rev. 48:149-151. 1958.
772. _____. Les programmes lineaires stochastiques. Revue d'economie politique. 1957:3-10. 1957.
773. _____. Makroökonomische modelle für die österreichische wirtschaft. Zeitschrift für Nationalökonomie. 17:262-282. 1957.
774. _____. (Book review) Mathematische Statistik. by: B.L. Van der Waerden. Springer Verlag Göttingen, Berlin, Heidelberg. 1957. Grundlehren der mathematischen Wissenschaften. Bd. LXXXVII.VI und 360 S., Ganzl. 49.60 DM. Mitteilungsblatt für Mathematische Statistik. 9:157. 1957.

775. _____. La teoria dei giochi, la programmazione lineare e l'analisi delle interdipendenze strutturali (1). L'industria (Rev. Political Econ., Italy). Issue No. 3. pp. 505-537. 1957.
776. _____. La teoria dei giochi, la programmazione lineare e l'analisi delle interdipendenze strutturali (2). L'industria (Rev. Political Econ., Ital). Issue No. 4. pp. 653-671. 1957.
_____, Associate Editor and Book Review Editor. Econometrica.
_____, Associate Editor. Statistische Vierteljarhresschrift.
_____, Associate Editor. Unternehmensforschung - Operations Research.
777. Tollon, B.C., Riley Schaeffer and Harry J. Svec. Mass spectral studies of trimethyl boron. Jour. Inorganic and Nuclear Chem. 4:273-278. 1957.
778. Town, G.R. The television allocations study organization - Its objectives and progress. Inst. Radio Eng., Trans. Prof Group on Broadcast Trans. Systems. PGBTS-19:70-75. 1957.
779. _____. A report on the engineering activities of TASO. Proc. Eng. Conf., 36th Ann. Con. Nat. Assoc. Broadcasters, Los Angeles, Calif. May, 1958.
780. _____. TASO and allocations. Nat. Assoc. Educ. Broadcasters Jour. 17(3): 7-9,31-34. 1957.
781. _____. The television allocations study organization. Elect. Eng. 77(2): 126-128. 1958.
782. Trapp, A.L., F.K. Ramsey, L.E. Whiteman, D.L. Baker and M.W. Sloss. A case report of Cushing's syndrome in the dog. Iowa State Coll. Vet. 20(1): 16-18. 1958.
_____, joint author. See under Ramsey.
Trapp, O.U., joint author. See under Fox.
Triplehorn C.A., joint author. See under Everett.

783. Ulmer, Martin J. Schistosome dermatitis at Lake Okoboji, Iowa. Jour. Parasitology. 44:13-14. 1958.
Underbjerg, K.L., joint author. See under Swenson.

784. Van Zante, Helen J. Do you have adequate housepower? Iowa Farm Science 11(12):15-17. 1957.
Veatch, C., joint author. See under Burger.
785. Vest, R. W., M. Griffel and J.F. Smith. Heat capacity of sodium tungsten bronzes from 1.8 to 4.2°K. Jour. Chem..Phys. 28:293-296. 1958.
_____, joint author. See under Griffel.
786. Viets, Frank G., Jr. and John J. Hanway. How to determine nutrient needs. U.S.D.A., Yearbook - Soil. pp. 172-184. 1957.
Voelker, D., joint author. See under Arnold, F.
787. Vischochil, R.K., R.L. Handy and D.T. Davidson. Effect of density on strength of lime-fly ash stabilized soil. Highway Res. Board Bull. 183. Nat'l. Acad. Sci.-Nat'l. Res. Council Pub. 550. pp. 5-15. 1958.
Voigt, A., joint author. See under Diehl, Moser, Richardson.
788. Von Krosigk, C.M. and Jay L. Lush. Effect of inbreeding in holsteins. Jour. Dairy Sci. 41:105-113. 1958.

789. Wadsworth, E., F.R. Duke and C.A. Goetz. Present status of cerium(IV)-cerium(III) potentials. Anal. Chem. 29:1824-1825. 1957.
790. Wakeley, Ray E. How changes in population, family and community affect agricultural adjustment. I.S.C. Special Rept. No. 20. A Basebook for Agricultural Adjustment in Iowa, Part I. pp. 33-37. 1957.
791. Walker, Homer W. and John C. Ayres. Studies on the characterization and resistance of the microflora of poultry. Bact. Proc. p. 15. 1958.
_____, joint author. See under Carlin.

Wallace, A.T., joint author. See under Simons.
Wallace, T.C., joint author. See under Hansen, R.S.
Wallenmeyer, W.A., joint author. See under Kerst.

792. Walstrom, R.J. Effects of flight distomus from honey bee colonies on red clover seed yields. Jour. Econ. Ent. 51:64-67. 1958.

793. Walther, P.R. and L.Z. Keep layers in cages? Iowa Farm Science 12(2): 9-11. 1957.

794. Ward, Ruth M. and R.S. Allen. Silage evaluation: Polyunsaturated fatty acids in legume-grass silage. Agric. and Food Chem. 5(10):765-767.

Warning, M., joint author. See under Hardy.
_____, Textiles and Clothing Editor. Iowa Farm Science.
Weakley, F.B., joint author. See under McKinney.

795. Webb, John R. and John Pesek. A situation report - Water-soluble phosphates. Iowa Farm Science. 12(8):7-10. 1958.

796. Weber, A.F. and J. Thomas Bell. Studies of the bovine adrenal gland. II. The histological and cytochemical effects of the administration of 1,1 dichloro-2,2-bis(P-chlorophenyl) ethane on the adrenal cortices of dairy calves. Amer. Jour. Vet. Res. 19:51-57. 1958.

797. Weber, C.R. Selection for yield in bulk hybrid soybean populations with different plant spacings. Agron. Jour. 49:547-548. 1957.

798. _____. Iowa soybean variety tests 1951-1957. Agric. and Home Ec. Ext. Ser. Agron. 419. 4 pp. 1958.

799. _____ and Theodore W. Horner. Estimates of cost and optimum plot size and shape for measuring yield and chemical characters in soybeans. Agron. Jour. 49:444-449. 1957.

800. _____ and Staniforth, D.W. Competitive relationships in variable weed and soybean stands. Agron. Jour. 49:440-444. 1957.

801. _____, _____ and W.G. Lovely. A killer for weeds in soybeans. Iowa Farm Science. 12(10):19-21. 1958.

_____, joint author. See under Staniforth.
_____, Editorial Board. Iowa Farm Science.
Weintraub, R.L., joint author. See under Orgell.
Weipert, E.A., joint author. See under Gilman.

802. Weller, Milton W. An automatic next-trap for waterfowl. Jour. Wildlife Management. 21:456-458. 1957.

803. _____. Observations on the incubation behavior of a common nighthawk. The Auk. 75:48-59. 1958.

Wells, H.D., joint author. See under Shurtleff.

804. Welp, T.L., L.A. Thomas and H.R. Dixon. A correlation and structural interpretation of the Missourian and Virgilian rocks exposed along the middle traverse of Iowa. Proc. Iowa Acad. Science 64:416-428. 1957.

805. Wenkert, Ernest. (Book review) The Chemistry of Natural Products. Vol. I. The Alkaloids. by: K.W. Bentley. Jour. Amer. Chem. Soc. 80:2030. 1958.

806. _____ and N.V. Bringi. The absolute configuration of some indole alkaloids. Jour. Amer. Chem. Soc. 80:3484. 1958.

807. _____ and James W. Chamberlin. On the stereochemistry of the pimaric acids. Jour. Amer. Chem. Soc. 80:2912. 1958.

808. _____ and B.G. Jackson. Partial degradation and reconstitution of podocarpic acid. A novel method of hydrolysis of highly sterically hindered esters. Jour. Amer. Chem. Soc. 80:217-219. 1958.

809. _____, _____. Rearrangements and oxidations of tricarbocyclic diterpenes. Jour. Amer. Chem. Soc. 80:211-217.

810. _____, Ernest W. Robb and N.V. Bringi. The stereochemical interrelationship of the yohimbine-type alkaloids. Jour. Amer. Chem. Soc. 79:6570. 1957.

811. _____ and D.K. Roychaudhuri. Oxidation-reduction studies in the realm of indole alkaloids. Jour. Amer. Chem. Soc. 80:1613-1619. 1958.

Werkman, C.H., joint author. See under Hug, Ott, Suzuki.
_____, Editor. Archives of Biochemistry and Biophysics.

_____, Assistant Editor. Enzymology.
_____, Assistant Editor. Iowa State College Journal of Science.
812. Wheat, J.G., R.E. Atkins, K.J. Frey and E.S. Dyas. Iowa barley and flax variety tests, 1953-1957. Iowa State Coll. Agron. Leaflet No. 418. 1957.
813. _____, _____, _____, _____. Iowa winter and spring wheat variety tests, 1953-1957. Iowa State Coll. Agron. Leaflet No. 417. 1957.
814. _____, _____ and J.G. Jarvis. Effects of nitrogen fertilizer and oat drill-row spacings on agronomic and quality characteristics of oat - legume seedings. Iowa State Coll. Jour. Sci. 32:39-56. 1957.
815. _____, K.J. Frey, J.A. Browning, R.E. Atkins and E.S. Dyas. Iowa oat variety trials summary, 1953-1957. Iowa State Coll. Agron. Leaflet 413. 1957.
_____, joint author. See under Atkins.
White, R.J., joint author. See under Rojas.
816. White, W.C., L. Dumenil and John Pesek. Evaluation of residual nitrogen in soils. Agron. Jour. 50:255-259. 1958.
817. Whitely, J.R. W.I. Thomas and I.J. Johnson. Cross-incompatability in maize. Agron. Jour. 49:513-518. 1957.
Whiteman, C.E., joint author. See under Ramsey, Trapp.
818. Wiggans, S.C. and K.J. Frey. The ratio of alcohol- soluble to total nitrogen in developing oat seeds. Cereal Chem. 35:235-239. 1958.
819. _____, _____. Tillering studies on oats. III. Effect of rate of planting and test weight. Agron. Jour. 49:549-551. 1957.
_____, joint author. See under Frey, Gardner, F.P.
Wiggins, J.A., joint author. See under Hamblin.
Wikén, T., joint author. See under Buchanan.
Wilbur, R.D., joint author. See under Quinn.
Will, D.H., joint author. See under Booth, Swenson.
820. Williams, D.E. and W.H. Pechin. The tantalum-columbium alloy system. Trans. Amer. Soc. of Metals. 50:1081-1089. 1958.
821. Willis, Elisabeth and Pearl Swanson. Expanding demand for farm products through improved nutrition. Iowa State College Spec. Rept. No. 21. in: A Basebook for Agricultural Adjustment in Iowa. pp. 40-42. 1957.
822. Willis, W.O., W.E. Larson and Don Kirkham. Corn growth as affected by soil temperature and mulch. Agron. Jour. 49:323-329. 1957.
_____, joint author. See under Larson.
823. Wilsie, C.P. Effect of inbreeding on fertiligy of alfalfa. Agron. Jour. 50:182-185. 1958.
_____, joint author. See under Gross, Marcus, Peacoch.
824. Wise, G.H., N.L. Jacobson, R.S. Allen and S.P. Yang. Rate of absorption of carotene and of vitamin A from the alimentary tract of dairy calves. II. Effects of methods of dispersion and of administration. Jour. Dairy Sci. 41:143-151. 1958.
825. Wittenberg, D. and H. Gilman. An intramolecular cleavage reaction of silicon-containing organolithium compounds. Jour. Amer. Chem. Soc. 80: 2677-2680. 1958.
_____, joint author. See under Gilman.
826. Wolfenbarger, Dan and E.T. Hibbs. Onion thrips (Thrips tabaci Lind.) infesting cabbage. Jour. Econ. Ent. 51:394-396. 1958.
_____, joint author. See under Hibbs.
827. Wolins, Leroy. (Book review) Introduction to Statistical Analysis. by: Wilfrid J. Dixon and Frank J. Massey, Jr. Ed. 2. McGraw-Hill Book Co. 1957. Personal Psych. 10:561-562. 1957.
828. Woods, W. R., W.D. Gallup and A.D. Tillman. Nutritive value of some protein supplements for sheep as determined by growth, digestibility and nitrogen retention. Jour. Animal Sci. 16:675-680. 1957.
Woody, R.W., joint author. See under Hansen, R.S.

Yamamura, S.S., joint author. See under Fritz.
Yang, S.P., joint author. See under Wise.
Yao, Y., joint author. See under Shaw, R.H.

829. Yates, Norris W. Antebellum southern humor as a vehicle of class expression. Bull. Central Mississippi Valley Amer. Studies Assoc. 1:1-6. 1958.

830. Yoder, Lester. New intermediates for the synthesis of androgenic groups. Proc. Iowa Acad. Sci. 64:247-251. 1957.

Zaweski, E.F., joint author. See under DePuy.

831. Zimmack, Harold L. and Tom A. Brindley. The effect of the protozoan parasite *Perezia pyroustae* Paillot on the European corn borer. Jour. Econ. Entomol. 50(5):637-640. 1957.

Zimmerman, D., joint author. See under Hays.

832. Zimmermann, William J. and Earl D. Hubbard. The incidence of parasitism in Iowa cattle. Iowa State Coll. Vet. 20(2):96-100. 1958.

833. Zucker, H., V.W. Hays, V.C. Speer and D.V. Catron. Evaluation of pumpkin seed meal as a source of protein for swine using a depletion-repletion technique. Jour. Nutrition. 65:327-334. 1958.

_____, joint author. See under Quinn.

Zuech, E.A., joint author. See under Gilman.